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Effect of morphological algorithms on medical imaging

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Abstract: Handling and improving the quality of medical images with the help of computer software is one of the important stages in the diagnosis and treatment. In this article, we focus on describing the new morphological algorithms by ITK (Insight Segmentation and Registration Toolkit). These morphological operators eliminate noise, detect good edges, and overcome the drawback of traditional edge detection methods.

Keywords: *Medical image processing, edge detection, image enhancement, morphological algorithms, ITK.*

I. INTRODUCTION

Most of the medical images (X-ray, CT-Computed tomography, and MRI- Magnetic resonance imaging) have very low contrast and its grayscale values corresponding to the same tissue change dramatically in comparison to conventional image formats. Because many objects are obscured or invaded by neighboring tissues, it is difficult to distinguish the edges of the object of interest and its surroundings. Another cause, one of the most common degradations in medical images is noise [1].

Image processing technology in health has attracted many researches in recent times. Classic edge detection methods in [2,3,4,5] using first and second derivatives detect good edges but sensitive to noise. Ishani Thakur and Manish Kansal [6] have summarized various methods for reducing noise on medical images. The method proposed by Rohini Paul Joseph et al. [7] used a series of algorithms to detect and extract brain tumors on MRI. The edges are defined by the gradient and K-mean methods.

But this approach is overexposed and produces a lot of false edges, so the results are not accurate. Gamma correction is also proposed to improve the quality of medical imaging By modifying the gamma value of each individual pixel [8].

For improving the quality of such image, a technique that removes unwanted components but does not alter the structure of the original image is necessary. This article proposes a new contrast enhancement technique from medical images using morphological algorithms, which replace the low-performance classical methods. Its main idea is to use a structural element that moves across the image. Morphology can be used instead of many pre-and post-processing techniques, depending on the purpose of the user [9].

Because of the flexibility and variety of structural element shapes, morphological operators can remove noise and smooth images as preprocessing filters. It can also enhance and

highlight the boundaries as clearly as the edge detection methods. Morphology depicts the relationship between objects in an image, especially complex gray-scale images such as medical images. The ultimate aim is to enhance the image obtained from medical devices and assist the clinician in making accurate diagnosis conclusions.

The efficacy of the proposed method has been demonstrated by experimental results performed on CT and MRI images on the basis of the ITK [10] tool.

This paper is divided into 3 parts: Part 2 introduces the approach. Part 3 presents the operation of 4 morphological algorithms. Part 4 gives the results, advantages, and disadvantages of each method implemented in the medical image.

II. METHODS

A. Factors affecting image quality CT, MRI scan

The HU unit measures the attenuation of the X-ray beam in each projection in CT scan:

$$I / I_0 = e^{-\mu x} \quad (1)$$

Where: I_0 is the initial intensity of the X beam, I is the intensity of the beam at the detector, μ is the linear attenuation coefficient, and x is the thickness of the reconstruction matrix [11]. Because the thickness of the material along the X-ray beam transmitted through multiple pixels, the measurement is the sum of the attenuation of the individual pixels. The pixel value assigned to the image is called the HU or pixel intensity (Hounsfield unit). If μ is the average linear attenuation coefficient for the interest pixel and μ_w is the attenuation value of the water, the HU is calculated by [12]:

$$HU = (\mu - \mu_w) / \mu_w \quad (2)$$

The tissue density can vary considerably and many soft tissues have overlapping ranges between HU values so that HU values do not clearly distinguish between different types of soft tissues. This is explained by the attenuation of X-rays in low energy regions that depend on Compton scattering and photoelectric effect. The intensity of normal brain tissue and tumor region are divided into groups. Medical images consist of pixels of varying intensity. These regions have small boundaries and HU, so edge detection is difficult. However, the pixel intensity values in these regions are still different [13].

Noise is a part of the information that creates the actual image because the noise is irrelevant data and there is no direct relationship to the actual image. So noise is a random phenomenon that is present in all real signal processing systems, with many sources of noise. For example due to insufficient photon to detector; the change in sensitivity of the detector, transmission error, the overlap of different tissues at the same slice; the movement of the patient; beam hardening phenomenon, the metal (which exceeds the maximum attenuation value that the CT can be reconstructed),... There are 3 types of noise: additive noise, Gaussian noise, salt & pepper noise [8]. CT, MRI images are affected by Gaussian noise (due to the discrete nature of radiation) and salt & pepper noise (due to errors in data transmission, the error pixels are alternately carrying value of 0 or 1). As the number of projections increases, the "star" effect appears in the reconstruction process, called "artifact" [14]. Noise affects image quality and reduces the effectiveness of subsequent processing methods. Noise can be reduced by improving collimation, longer data acquisition time and circuit design, or applying image filters [15]. The sections below describe those filters.

B. Selection of structure element

The morphological algorithms commonly used include erosion, dilation, opening, and closing. Structural elements are the basic components of morphological algorithms [16]. The selection of shape (square, disk, ring,...) and size (3x3, 5x5, 7x7,...) of the structural element directly affects the resulting image (Fig. 1). The structure

element is a matrix of two values of 0 and 1, where 1 is defined as neighboring pixels. It depends on the object size and the resolution of the image. According to the theory of image analysis, the smaller the structural element, the less the ability to filter noise, but can detect small edges and vice versa. In the medical image, depending on the subject of interest that select different conservation details.

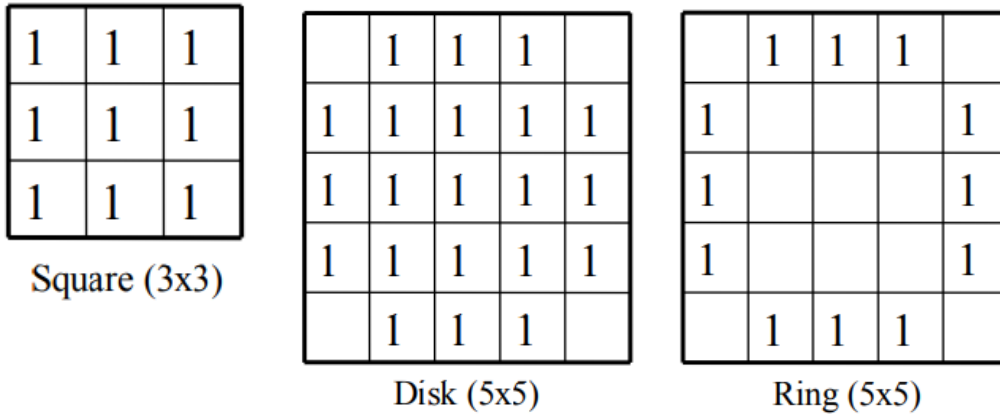


Fig. 1. Shapes of the structural element.

C. Dilation, Erosion, Opening, Closing

1. Binary morphology

Erosion and dilation are new measures in image segmentation, edge detection, skeleton extraction,... Dilation is the process of extending the features by scanning structural elements across the entire image. Pixels are added to the boundaries of objects and are set in the maximum during dilation. In contrast, the erosion process reduces the features. The principle of operation of this process is that the pixels are set to the minimum to remove the corresponding pixels from the object boundary of the structural element.

Opening operation is the function of dilation and erosion in which the structural element is rolled along the inner boundary. Closing operation is the function of erosion and dilation in which in which the structural element is moved along the outer boundary [17].

In the binary image,

A – Original Image and,

B – Structuring Element

They are defined as:

Dilation: A is dilated by B, written as $A \oplus B$, is defined as (3):

$$A \oplus B = \{a+b \mid \text{for some } b \in B \text{ and } a \in A\} \tag{3}$$

Erosion: A is eroded by B, recorded as $A \ominus B$, and defined as (4):

$$A \ominus B = \{p \mid b+p \in A \text{ for every } b \in B\} \tag{4}$$

Opening is the implementation of turn B to erosion A and b continue to expand resulting matrix obtained, written as $A \circ B$, is defined as (5):

$$A \circ B = (A \ominus B) \oplus B \tag{5}$$

Closing is the opposite of opening, B dilates on A and B continue to erode the result obtained, written as $A \bullet B$, is defined as (6):

$$A \bullet B = (A \oplus B) \ominus B \quad (6)$$

2. Gray-scale morphology

$A(x,y)$ is a gray-scale two-dimensional image. $B(a,b)$ is structuring element.

Dilation, erosion, opening, and closing of a gray-scale image $A(x,y)$ by a gray-scale structuring element $B(a,b)$ are denoted respectively by (7), (8), (9), (10) [18]:

$$(A \oplus B)(x,y) = \max\{A(x-a,y-b) + B(a,b)\} \quad (7)$$

$$(A \ominus B)(x,y) = \min\{A(x-a,y+b) - B(a,b)\} \quad (8)$$

$$(A \circ B)(x,y) = (A \ominus B)(x,y) \oplus B(a,b) \quad (9)$$

$$(A \bullet B)(x,y) = (A \oplus B)(x,y) \ominus B(a,b) \quad (10)$$

Similar to binary image, erosion reduces or thins the grayscale scale size of the object, eliminates excess noise and detail. Dilation increases or expands increases the grayscale scale size of the object, breaks the segment, fills the gaps. The effectiveness of the dilation and erosion algorithms is obvious for border detection, but the interference filtering is limited [19].

As mentioned above, the combination of the erosion and dilation operators to overcome the disadvantages of using each single operator. The open operator helps smooth the boundary, eliminates the narrow discontinuous (for areas smaller than the structural element), and removes the convex part. As opposed to opening, closing operator also eliminates interference, clears up small holes, filling holes in the object border [20].

Because the individual use of binary operators and rigid binary operators is not flexible at the user's discretion. The combination of two operators solves a number of cases such as: dilation of critical detail while removing excess or interstitial space (the only dilation does not do this). Or just erase noise, while the object size does not change (only erosion does not do this).

III. RESULTS

We evaluated the effectiveness of these algorithms based on the ITK 4.11.0 (Insight Segmentation and Registration Toolkit) image processing library. The images used in the article are taken from the Da Nang Hospital, 108 Military Central Hospital.

Figure 2, 3, 4, 5 shows the results of 4 images obtained after performing morphological algorithms. Clearly, the output images are improved optimally over the original images. The obtained images are calibrated to prevent boundary effects and maintain the background values of the original image. From Figure 2, we can see that the dilation operator increases the number of bright pixels and decreases the number of dark pixels. The final image has a uniform intensity distribution over the original image. Figure 2, 3 shows the different results of the 3x3, 5x5 structural elements. Contrast increases with size, 3x3 mask gives best results. But the edges are not preserved when the size of the structural element increases and results in hardly visible internal structures. Erosion algorithms also perform enhanced over the original image. It has darker pixels that are optimized along the edges and blur its edges. Erosion eliminates small details but its downside is to darken the image. Conversely, dilation will increase the brightness of all pixels. Figure 2 also increases the overall

contrast. The dilation creates some dark pixels at the bottom of the colon image. This proves that there is a clear edge division and the wrong points are removed, but still preserve the structure of the image. Figure 4, 5 are the corresponding result of morphological opening, closing. We can see that the dark pixels are removed but the bright pixels are not affected. The opening is capable

of extracting the skeleton of the image. It fills in small gaps in the image and highlights the subject for easier identification. Finally, the results of Figure 5 show that the edges of MRI images of the brain, abdomen, and intestines are completely detected and distinguished when performing the subtraction of the original image and morphological image closing.

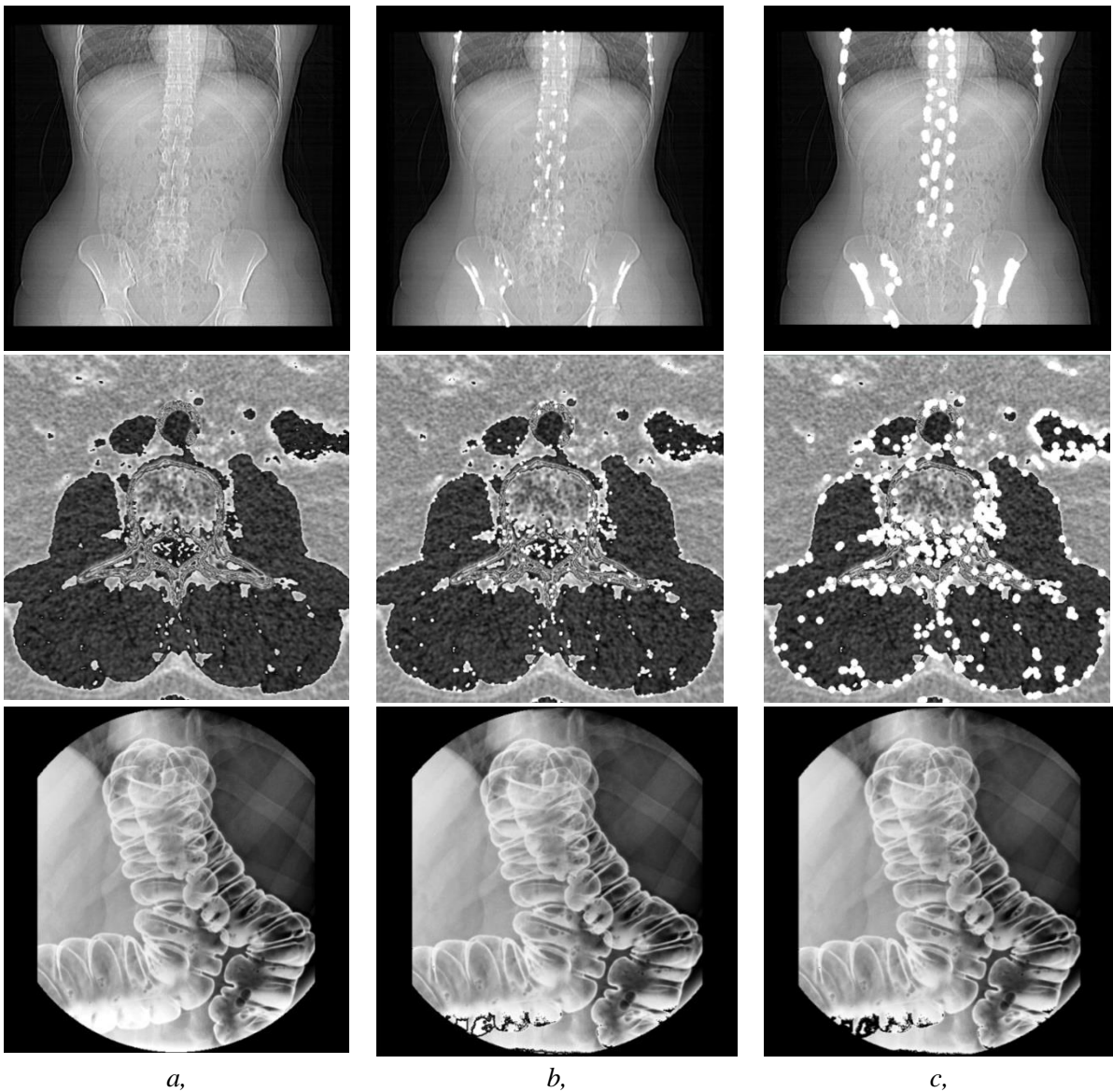


Fig. 2. (a) Original image; (b), (c) respectively, is the obtained image with the 3x3, 5x5 structure elements of morphological dilation. (1,3) take from ITK example data with MRI of the abdomen and intestines [21];(2) of patient Le Quang T with head, take from Da Nang Hospital.

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In general, the structure of the liver, lungs, head,... and other organs has been enhanced and shown clearly by morphometric operations. Contrasts of the entire target area of interest are improved. The greatest advantage is that the border areas have low contrast and visually impaired lungs, liver, injured parts,... are clearly defined. The morphological method yielded clear results in the diagnosis of

laryngopharyngeal symptoms, aortic aneurysm, and colonic pain.

The disadvantage of the above methods is that the structural element moves in a fixed direction over the image, so noise can be created at the periphery of the object of interest. The target image gets more complicated in this case.

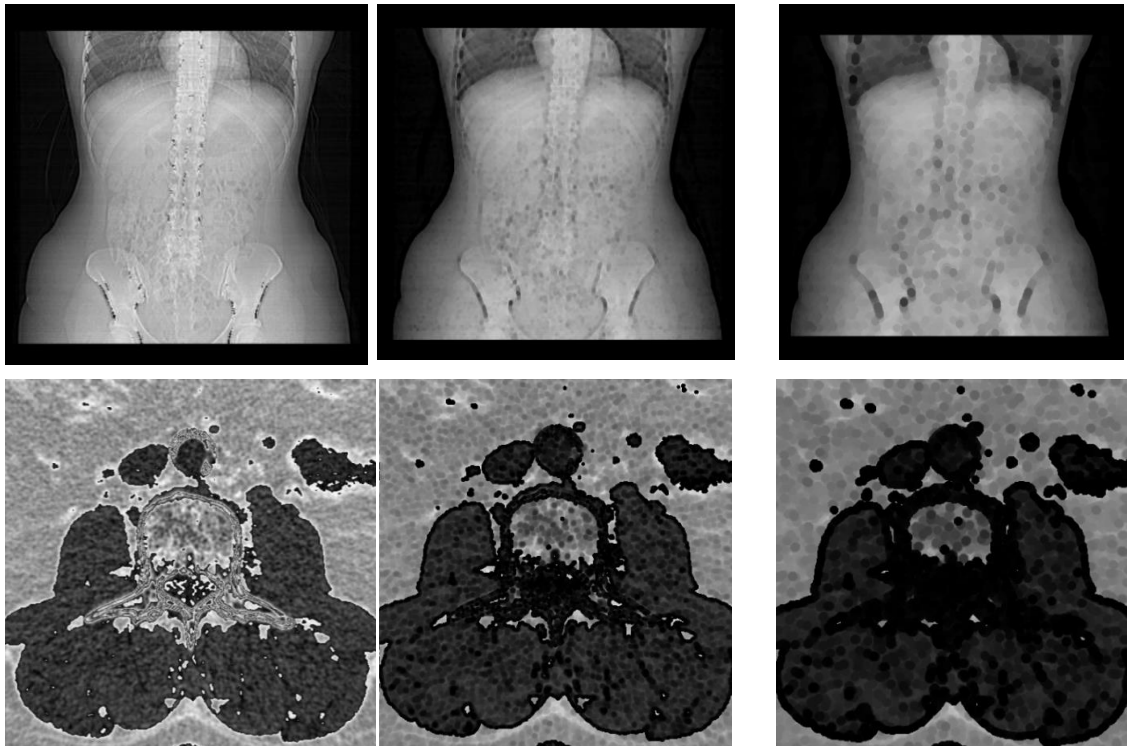


Fig. 3. (a) Original image; (b), (c) respectively, is the obtained image with the 3x3, 5x5 structure elements of morphological erosion.

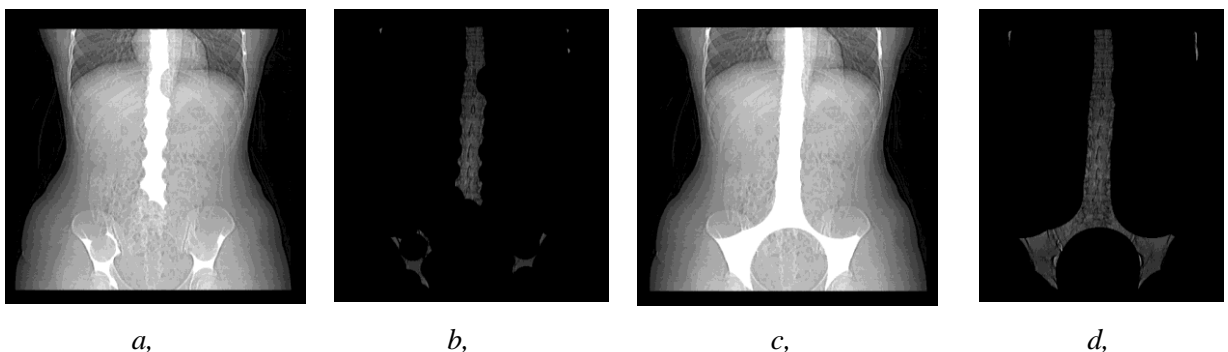


Fig. 4. (a) is the image obtained with the 3x3 structure element; (b) Original image - image (a); (c) is the image obtained with the 5x5 structure element; (d) Original image - image (c) of the morphological opening.

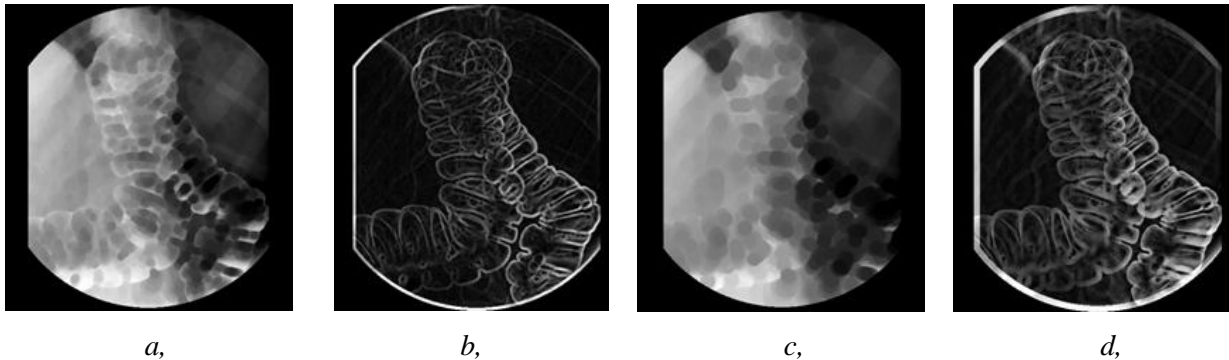


Fig. 5. (a) is the image obtained with the 3x3 structure element; (b) Original image - image (a); (c) is the image obtained with the 5x5 structure element; (d) Original image - image (c) of the morphological closing.

IV. CONCLUSIONS

By approach based on shape, morphology is the new method used in image analysis and processing instead of traditional methods. Experimental results show that this method improves contrast and detects sensitive edges of medical images. The advantage of this method is not to confuse the edges with neighboring objects, preserving the edges clearly. Dilation, erosion, opening, and closing improve the quality of the entire image without distinguishing pixels from each other so noise is eliminated. It effectively supports the segmentation and extraction of tumors and lesions at later stages.

In the next time, we will study new algorithms to automatically detect tumors by combining morphological algorithms, edge detection algorithms, image segmentation algorithms, and image enhancement,... in both anatomical and functional images. By evaluating, simulating physical processes in reconstruction, image processing is a new direction for the application of nuclear technology in medicine.

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