COMPUTED TOMOGRAPHY IMAGE PROCESSING ALGORITHMS ANALYSIS

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Abstract. *Medical images have been widely used in disease monitoring, treatment planning, diagnosis, and computer-assisted surgery. Often, the acquired images are raw in nature, which makes them prone to being complex and noisy. Therefore, a series of pre-processing and information extraction steps are necessary for the relevant information to reach the doctor. To this end, image cleaning and edge detection play an important role as a precursor for advanced techniques in the field of medical image processing. In this paper, we proposed an innovative mathematical morphology-based image cleaning and edge detection method for pre-processing human heart computed tomography (CT) images.*
Keyword*. Medical, Image, algorithms, detection algorithms, Sobel, element.*

I.INTRODUCTION

Medical imaging has been a major breakthrough in disease monitoring, treatment planning, diagnosis, and computer-assisted surgery. However, most medical imaging systems are prone to introducing noise and artifacts into the image during the acquisition process [1] , [2] , which leads to image quality degradation. Raw images require several preprocessing steps, such as denoising and edge detection, to improve the image quality before they can be properly analyzed by a processor and ultimately delivered to the physician.

Image denoising is the process of restoring the original image from its "polluted" version, usually by reducing noise [3] . In other words, denoising strategically removes unwanted noise from an acquired image while preserving its important details. The process plays an important role in preprocessing for many applications in medical imaging. Furthermore, the accuracy of the denoising algorithm is crucial in the edge detection stage. The presence of noise inevitably affects and degrades the performance of edge detection. Edges are the intensity variations or discontinuities between pixels in a digital image that represent structural information and reflect the nature of the image object [4]. Edge detection is defined as the process of detecting and locating sharp discontinuities based on image features such as intensity and texture. Traditional edge detection algorithms such as Roberts, Sobel, Prewitt, Laplace, and Canny operators are spatial domain-based and theoretically classified as high-pass filters. Given that both noise and edges contain high-frequency components within an image, these algorithms are not very effective in extracting edges from complex and noisy scenarios such as CT and ultrasound [5] [6]. Transform-based edge detection methods, such as wavelet transform [1], on the other hand, although capable of effectively suppressing noise, cannot perform in real time due to the large amount of computation [7].

II.RELATED WORKS

Mathematical morphology is a popular alternative used in image processing and analysis based on the concept of shape derived from set theory [8]. It has been identified as one of the most popular methods for image denoising and edge detection. This is partly due to the poor performance of classical edge detection methods in the presence of noise [5], [6], [9]. In mathematical morphology, images are considered as sets. The morphological changes obtained by Minkowski addition and subtraction are determined to extract potentially useful features in the images. It is a nonlinear transformation that uses a structuring element to interact with the input image to extract important image information. Among its advantages, morphology-based methods have been proven to be good at preserving image features while removing noise, as well as good for different scale edges and short computation time [10]. also proposed a morphological edge detection algorithm based on eight5 times5eight dimensional structural elements in different directions, where the final edge results are obtained using a synthetic weighting method. Tests on grayscale image datasets have shown that this edge detection algorithm is more efficient compared to morphological edge detection based on single and symmetric structural elements. In addition, Kumar et al. [5] presented an improved mathematical morphology-based image denoising and edge detection algorithm by introducing different shaped structural elements. The proposed algorithm is able to suppress impulse noise in lung CT images when detecting lung edges. Experimental results show that the algorithm achieves better results than Sobel, Canny and traditional morphological edge detectors, which use a single rigid shaped structural element. In this paper, we extend the work in [5] and propose a mathematical morphology-based image enhancement system that includes image denoising and edge detection, removes unwanted noise, and also detects important edges in CT cardiac images. The image data modality used in the experiments is two-dimensional computed tomography (CT) slices including parasternal long-axis view, parasternal short-axis view, and four-chamber view of the human heart obtained from the National Heart Institute (Institut Jantung Negara) in Malaysia. The rest of the paper is organized as follows. In Section II, we provide basic knowledge on the theory of mathematical morphology. Section III describes the flow of our proposed methodology for denoising and edge detection of CT cardiac images based on mathematical morphology. Section IV shows and discusses the experimental results obtained with the proposed method. Finally, Section V concludes the paper with a conclusion.

III. MATERIALS AND METHODS

The selection of the structural element and the design of the morphological filter structure are two key factors in determining a successful morphological edge detection algorithm. The selection of the structural element should be done correctly based on the characteristics of the target image. This step is very important because different structural elements determine the geometric information to be analyzed. In addition, the size and shape of the structural element can also affect the edge detection result. As a result, basic morphological operations such as expansion, erosion, opening and closing can be controlled or combined to design and build an edge detection morphology filter. The following are the methods for detecting morphological edges formed using basic morphological operations [11]. Expansion residual edge detector: the edge of the image, represented by Ed(I). This detector is defined as the difference between the expanded domains of I and the domains of I.

$$E_d(I) = I + E - I \qquad (1)$$

Erosion remnant detector: the edge of the image I, is represented by Ee (I).

$$E_e(I) = I - I - E \quad (2)$$

BH is represented by (I). This closure is defined as the difference set of the domain and the domain I .

$$G(I) = I + E - I - E \qquad (3)$$

The proposed framework of the mathematical morphology-based CT Cardiac image denoising and edge detection method is shown in Figure 1. The image cleaning step is first used to remove the unwanted noise before extracting the edges. This is done by calculating the difference between the input image and the image after applying a median filter. The generated noise is then removed from the image. Next, the morphological smoothing step applies a 5 × 5 rectangular structure element with an anchor point at the center and a hat transformation to remove the remaining noise and smooth the image.Then, the contrast-limited adaptive histogram equalization (CLAHE) method is used to sharpen and enhance the contrast of the image [14]. CLAHE is an improved histogram equalization algorithm that incorporates a contrast-limiting feature to overcome the excessive noise enhancement caused by the traditional adaptive histogram equalization method [15]. In the morphological edge detection stage, we proposed six different structuring elements, all of which are 3 × 3 pixels with the anchor point centered at the center. This approach aims to effectively remove noise while preserving fine edges. The shapes of the structuring elements are shown below.

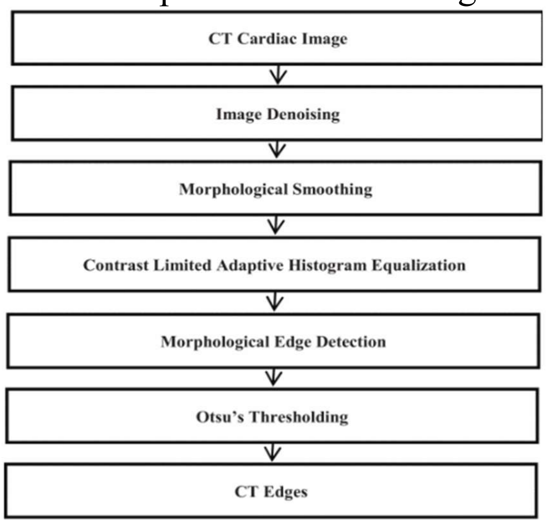

Figure 1. Block diagram of an image denoising and edge detection method based on mathematical morphology.

$$E_0 = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \qquad E_1 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

$$E_2 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 0 \end{bmatrix} \qquad E_3 = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

$$E_4 = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 1 & 0 \\ 0 & 1 & 0 \end{bmatrix} \qquad E_5 = \begin{bmatrix} 1 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 1 \end{bmatrix}$$

The definition of edge detection methods is as follows.

$$S_1 = S_i^5 = (M \cdot E_i) + E_i - (M \cdot E_i)$$
$$S_2 = S_i^5 = (M \cdot E_i) + E_i - (M \cdot E_i)$$
$$S_3 = S_i^5 = (M \cdot E_i) + E_i - (M \cdot E_i)$$

The input image is first subjected to morphological closure and opening operations for initial filtering and smoothing before edge extraction. The novelty of our algorithm lies in its optimal processing. To avoid the problem of over-smoothing, we process the image with only one structure element, E0, at this stage. Thus, the process maintains the efficiency of the algorithm while reducing the complexity and computational cost. Next, the different morphological edge detection methods highlighted in Equations 1, 2, and 3 are used to extract the gradient data of the CT heart image.

IV.EXPERIMENT RESULTS AND ANALYSIS.

The experiments were set up using the Microsoft Visual Studio 2010 platform with the OpenCV library. The experimental results are presented as follows. The image dataset used in this experiment is a computed tomography (CT) image of the parasternal long-axis view, parasternal short-axis view, and four-chamber view of the human adult heart, as shown in Figure 2. The dataset was obtained from patients tested at the National Heart Institute (Institut Jantung Negara, IJN) in Malaysia and was permitted to be used for research purposes.

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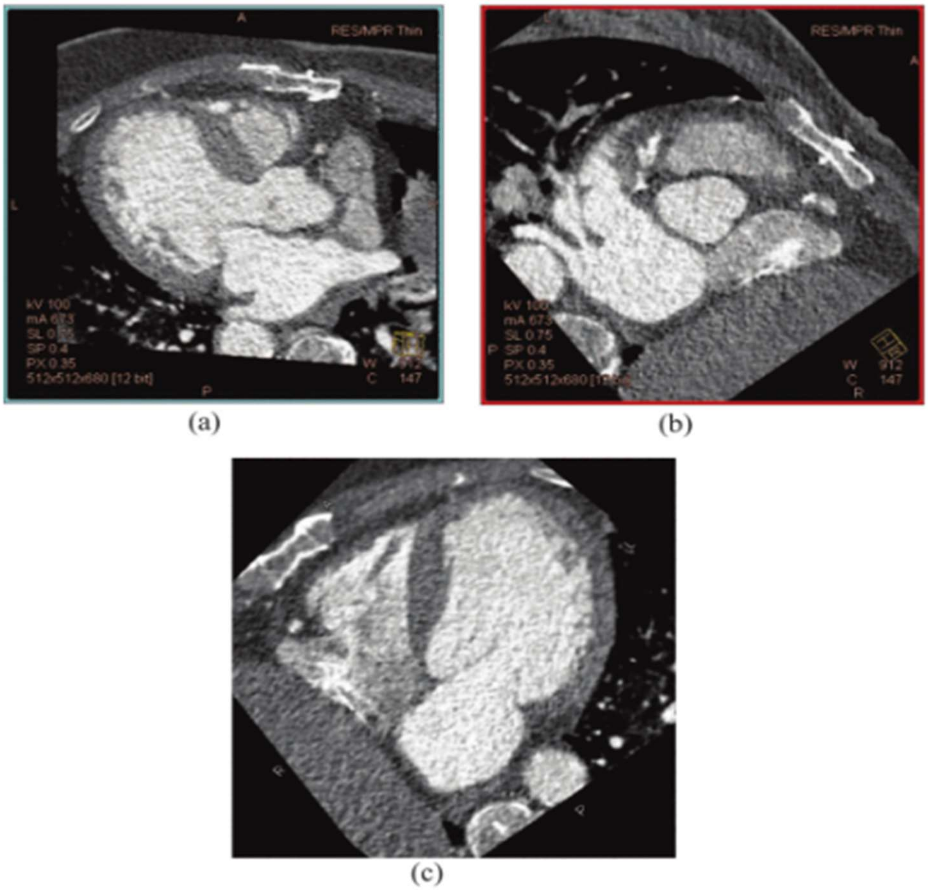

Figure 2. (a) Parasternal long-axis computed tomography (CT) image of the heart. (b) Parasternal short-axis view (c) and four-chamber view of the adult human heart.

The edges of the CT image are then extracted using a proposed method based on mathematical morphology. This method uses morphological edge detection algorithms that allow the detection of six different shapes of structural elements and all correct edges.

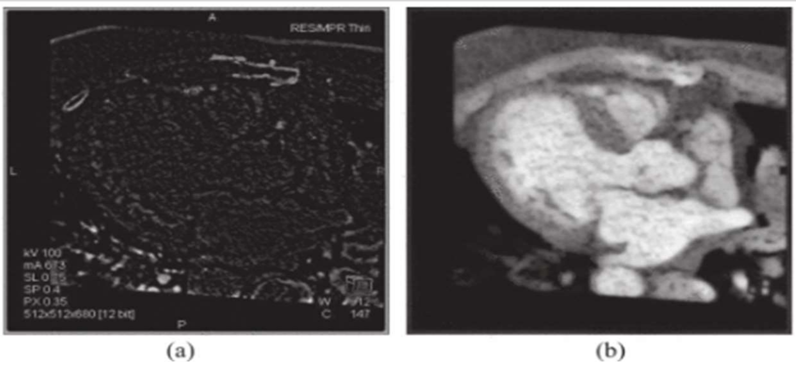

Figure 3. (a) Noise of a computed tomography (CT) cardiac image with a filtered parasternal long-axis view from the input image and the difference of the input image after applying a median filter. (b) Denoised and enhanced CT image.

V.CONCLUSION

This paper introduces an efficient method for image denoising and edge detection based on mathematical morphology to enhance CT cardiac images. Our approach to implement six different shapes of structural elements enables the algorithm to remove noise and identify important edge regions in human heart CT images. The above experimental results demonstrate that our approach is effective for enhancing noisy and complex images with low computational cost, which will be very useful for end-users of medical imaging systems.

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