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A Study on Image Processing Using Mathematical Morphological

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***Abstract*—Mathematical morphological image processing is one of the methods that provides enhancement to the image, improves the image by creating better imaging and focuses on the interest information for the image. Mathematical morphological is applied to the binary image using various characteristics of the structuring element (SE) for the purposes of observation and comparison. Mathematical morphological is programmed and run using the MATLAB simulation tools. The output result is obtained and clearly proven for each process in mathematical morphological. Based on the output result, mathematical morphological can enhance and improve the image, but the characteristic of the SE as the important probe, which is selected to suit the interest information on the image, can improve the morphological performance.**

Keywords—mathematical morphological; MATLAB simulation tools; structuring element; erosion; dilation

I. INTRODUCTION

In the medical arena nowadays, technologies are making a huge impact in providing media that offer promise [1]. These technologies can give deliver improvements in many ways by increasing the outcome validity, shortening processing time, reducing contamination of the process and much more. By using these technologies, human energy and errors can be reduced [2]. Thus, applying such technologies in the medical arena can be significantly transformative.

Image processing is one of the aforementioned technologies that are useful. Furthermore, DNA microarray image processing is one of the crucial processes in the medical arena, in which the process extracts the information from each spot on the microarray image [3], [4]. The process becomes complex because of the size of the spots. DNA microarray, which is important for gene discovery, is a technique to monitor several thousands of gene expressions simultaneously [5]. The results of the hybridization process on the solid surface array are scanned out, and a microarray image is produced [6]. During the scanning process, there may be a problem where the noises are included in the microarray image, resulting in a poor quality image. This situation can affect the information extraction of the image process. Thus, to avoid it from happening, enhancement and improvement of the images are needed for a better quality of images using image processing.

There are three stages to processing the microarray image, which are gridding, segmentation and intensity extraction [7]. Gridding simply indicates each spot location, while segmentation verifies the foreground and background on the images. Lastly, intensity extraction evaluates the intensity that is available on the images.

The noises on the microarray image lead to incorrect information extraction [8]. Therefore, morphological image processing is one of the solutions that, by using the basic erosion and dilation operations, can be the solution for the enhancement of microarray images. Morphological image processing, when using erosion and dilation operations, manipulates the operations to enhance the foreground on the image. The objective of the process is to differentiate between the foreground structure and the background structure on the image [9], [10]. The morphological performance is dependent on the characteristic of the SE.

This paper concerns the study of mathematical morphological image processing when performed on the input image in Fig. 1 using the MATLAB simulation tools. Section II discusses several methods that use mathematical morphological image processing, while section III describes the methodology of our work. In section IV, the experimental results of the mathematical morphological image processing of the input image are discussed. Lastly, the conclusions of our work are presented in section V.

II. LITERATURE REVIEW

In paper [11], X-ray microfluorescence (μXRF) and microtomography (μCT) were used to evaluate the bone mineral density (BMD) in the study of osteoporosis. The μXRF and μCT resulted in high resolution potential and non-destructive character on the trabecular bone during the evaluation of the bone quality. These experiments were performed using Wistar rats, which were categorized into control and ageing groups. The μCT used a charge-coupled device (CCD) video camera to observe the tomographic image in real-time. The greyscale image allowed for differentiation between the bone and the background. Later, the morphological filter was applied to the images, which eliminated the noises that were smaller than the SE, while the important structure of the bone remained. Next, the images were subjected to thresholding by Otsu's algorithm for segmentation. For the μXRF, the bone samples were taken out and cut, and then the samples were mapped in 2D with the aid of an optical microscope to investigate the calcium, zinc and strontium of the control and ageing groups. The chosen

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methods ensured that the BMD study led to the development of new drugs for the treatment of osteoporosis.

In paper [12], multi-scale top-hat transform (MTHT) and nonsubsampled shearlet transform (NSST) were used to fuse the Synthetic Aperture Radar (SAR), infrared and visible light images. The objective is to get a higher contrast and better edges of images. Firstly, by using NSST, the three original images were decomposed into low frequency subband coefficients and bandpass subband coefficients. Secondly, the MTHT extracted the effective bright and dark image features from low frequency subband coefficients. Then, the salient fused bright and dark features were obtained by using the pixel-wise maximum operation, with the subsequent fusion joining the low frequency combined coefficients. On the other hand, the local directional entropy reduced the noises of the SAR and infrared images on the fused image, after which the measurement was selected for bandpass subband combined coefficients. Finally, both the combined coefficients were inverted by NSST to obtain the fused image. The chosen methods improved the image contrast and preserved the image edges.

In paper [13], the multi-scale multi-structuring element was chosen in order to detect multiple linear features in images. The multi-structuring element was constructed for lines with different shapes, while the multi-scale was constructed for different sizes of linear features. Firstly, the multi-scale structuring element was considered as the reconstruction operator for multi-scale top-hat. Secondly, the multi-scale multi-structuring element as the reconstruction operator was analysed for linear features extraction. Thirdly, the multi-scale multi-structuring element was constructed. Finally, through image binarization and refinement steps, the lines with different shapes and lengths were obtained. The chosen method showed an effective extraction of multiple linear features compared with other similar methods.

In paper [14], a method using the multi-scale mathematical morphological-based algorithm was proposed for discrimination ability of invariant moment for similar object recognition and classification. Multi-scale mathematical morphology was shown to improve the operation. At the beginning, the multi-scale identified the details of the image at different scales, and then a combination of the details was calculated. Finally, a suitable measure for the different parts of several scales was used to differentiate the similar objects. These methods were more efficient and offered better comparison than the original invariant moments of original images. This method provided an efficient experiment result.

Paper [15], discusses the problems of a morphological image processing application for image enhancement and features detection. Four important problems were identified: cleaning the image of various types of noise or improving the contrast; detecting the known templates in the image; detecting the existence and location of geometric features, whose types are known but not their exact form; and, designing optimal morphological filters. The morphological filters countered the problems where the image objects were preserved, uncovered them or detected their geometric structure. Furthermore, morphological filters were seen to solve the nonlinear tasks better. The chosen method showed that optimal design, as well as scale-space formulation and implementation, can provide better image enhancement and features detection of the image.

Table I is a summary of the comparison between different applications that use mathematical morphological operations. Methods [14] and [15] used the binary image as their input, while the other methods use the colour, greyscale and SAR as their input. Only methods [11], [13], and [15] involved thresholding of the image, in which the threshold was simply to generate a standard level for the foreground and background of the image. Medium complexity was found in methods [11], [12], and [13] because the applications involved difficult processes and operations compared to the other two methods.

The method in [12] used MTHT and NSST to fuse the SAR, infrared and visible light images in order to improve the image contrast and preserve the image edges. For the method in [13] the multi-scale multi-structuring element was used to detect multiple linear features in the image and showed effective information extraction of multiple linear features. The method in [14] used multi-scale mathematical morphological in discrimination ability of invariant moment in order to recognize and classify the similar object. It was also very useful when identifying objects of different scale.

In this paper, the mathematical morphological operations are proposed to perform on the binary image and observe the interest part of the image. Several characteristics of SEs are used to compare in order to obtain an optimum output image. Every process of mathematical morphological is observable and the suitable SE is used for this work.

TABLE I. COMPARISON BETWEEN DIFFERENT APPLICATIONS

Paper	[11]	[12]	[13]	[14]	[15]
Application	BMD	Sensor technologies	Pattern recognition	Object recognition	Study case
Type of image	Colour	SAR	Greyscale	Binary	Binary
Threshold	Yes	No	Yes	No	Yes
Accuracy	N/A	N/A	N/A	N/A	N/A
Complexity	Medium	Medium	Low	Medium	Low
Special features	N/A	NSST and MTHT	Multi-scale multi-structuring element	Multi-scale mathematical morphological	N/A

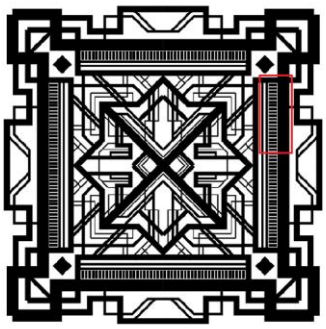

Fig. 1. Input image [16].

1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1

Fig. 2. Structuring element.

III. METHODOLOGY

This section discusses mathematical morphological image processing, in which each of the processes is programmed using the MATLAB simulation tools to perform on the input image. Fig. 1 is the input image that is used, while the red box on the top right of the input image indicates the main interest of this work. A rectangular shape with the width of eight pixels and the height of four pixels, as shown in Fig. 2, is used as the SE for the operations. The rectangular shape is chosen because the main interest has multiple rectangular boxes that stack vertically with a gap between them. Thus, the rectangular shape of the SE is suitable for use when performing mathematical morphological image processing on the input image.

A. Morphological Operations

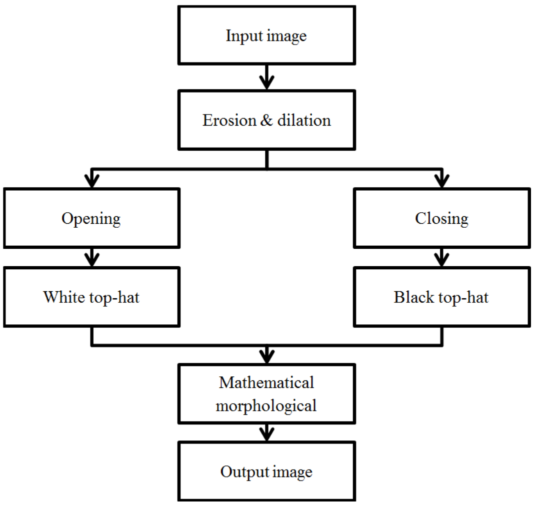

Fig. 3. Flow chart for mathematical morphological image processing.

Fig. 3 shows a flow chart for mathematical morphological image processing. The mathematical morphological processes have two major operations: white top-hat (WTH) and black top-hat (BTH) transformation. WTH is to enhance the foreground structures on the image using the different results found between the input image (IM) and the opening operation, while the BTH is to enhance the background structures on the image by the different results found between the IM and the closing operation. The mathematical morphological, WTH transformation and BTH transformation are derived as below: [17]

$$\text{Mathematical morphological} = \text{IM} + \text{WTH} - \text{BTH} \quad (1)$$

$$\text{WTH} = \text{IM} - \text{Opening} \quad (2)$$

$$\text{BTH} = \text{Closing} - \text{IM} \quad (3)$$

The opening process is to remove the foreground structures that are smaller than the SE. The closing process is to remove the background structures that are also smaller than the SE. These opening and closing processes manipulate the erosion and dilation process in order to gain the enhancement. The erosion process removes the foreground structures on the image, while the dilation process adds the foreground structure to the image. The erosion and dilation process is dependent on the SE because both processes use the same characteristic SE. Therefore, the characteristic of the SE are important because they can affect the morphological performance. The opening and closing operations are derived as below: [17]

$$\text{Opening} = \text{IM} \ominus \text{SE} \oplus \text{SE} \quad (4)$$

$$\text{Closing} = \text{IM} \oplus \text{SE} \ominus \text{SE} \quad (5)$$

where $\ominus$ and $\oplus$ denote the erosion process and dilation process, respectively.

B. Structuring Element

The SE plays an important role in mathematical morphological image processing in order to generate a better enhancement of image. Furthermore, the SE with the same size and shape is used for the erosion and dilation process. Using the different characteristics of the SE may give a different result for the mathematical morphological operation on the image. Besides, choosing a suitable SE is important because each image has its own pattern and depends on the structure that is required to be enhanced. Therefore, this work uses a rectangular shape for the SE because the objective is to enhance the rectangular boxes on the main interest, as shown in Fig. 1.

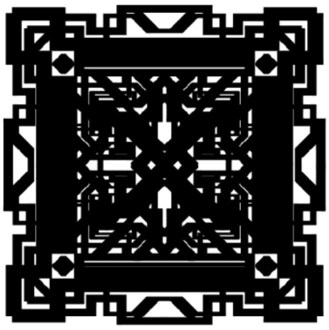

Fig. 4. Erosion process.

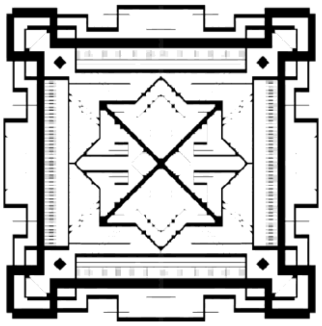

Fig. 5. Dilation process.

IV. Results and Discussion

In the previous section, we presented the morphological algorithm that was run on the input image, as shown in Fig. 1. In this section, the experimental results are presented using the SE, as shown in Fig. 2. This experiment was performed using the MATLAB simulation tools running on the Window 7 operation system with an Intel(R) Core(TM) i5-3210M processor.

The function of the erosion process is to shrink the foreground on the input image depending on the SE, as shown in Fig. 4. The results show that the foreground area has been decreased and the background area has been increased due to the shrinking of the foreground by the erosion process. The function of the dilation process is to enlarge the foreground on the input image depending on the SE, as shown in Fig. 5. The results show that the foreground has been increased and the background area has been decreased due to the increases to the foreground by the dilation process.

Once the erosion and dilation concepts are known, the next step involves the opening and closing process. The opening process is to remove the foreground structures on the image that are smaller than the SE. The opening results are shown in Fig. 6, in which the foreground structures that are smaller than the SE have been removed and, as a result, the background area has been increased.

The closing process removes the background structures that are also smaller that the SE. The closing results are shown in Fig. 7, in which the background structures that are smaller than the SE have been removed and, as a result, the foreground area has been increased. The opening and closing process have been followed in line with the mathematical theories as stated in (4) and (5), respectively. In other words, the opening process enhances the foreground structure and the closing process enhances the background structure.

Next, the WTH transformation is conducted in order to obtain the difference between the input image and the opening process as stated in (2), followed by the BTH transformation to obtain the difference between the closing process and the input image as stated in (3). The results of the WTH transformation are shown in Fig. 8, where the foreground structures indicate the exceeded foreground structures on the input image compared to the opening. The results of the BTH transformation are shown in Fig. 9, where the foreground structures indicate the exceeded foreground structures on closing compared to the input image.

Fig. 6. Opening process.

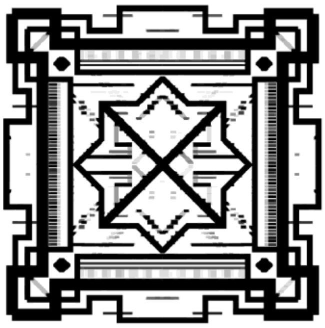

Fig. 7. Closing process.

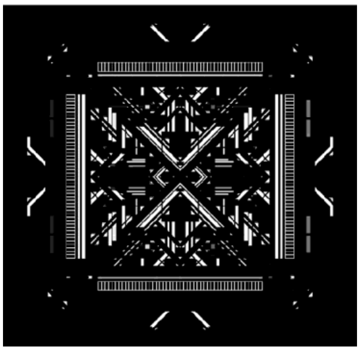

Fig. 8. White top-hat process.

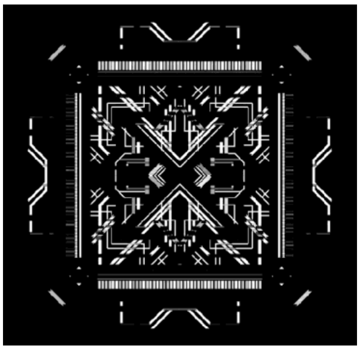

Fig. 9. Black top-hat process.

Fig. 10. Final mathemathical morphological process output.

The final step of mathematical morphological image processing, as stated in (1), is where the input image is add to the WTH transformation image and then subtracted from the BTH transformation image, as shown in Fig. 10. This image is much improved and enhanced when compare to the input image based on the main interest, as shown in Fig. 11.

After applying the mathematical morphological operations, a clear difference between the input image and the output image are shown in Fig. 11. The results are taken from the main interest stated in the red box, as shown in Fig. 1. The output image proves that mathematical morphological operations can enhance and improve the image, because the gap between the boxes becomes much clearer and sharper when compared with the input image. Furthermore, the gap between them can be controlled by the characteristic of SE.

A suitable characteristic of the SE is chosen for a better mathematical morphological performance. Fig. 12 shows the comparison of the output image using different characteristics of SEs. The results clearly show that the gap between the boxes is smaller compared to the others when using the 3x8 rectangular SE. The 6x8 rectangular SE is not compatible because the results show there are some narrow gaps. Thus, the 3x8 and the 6x8 SEs are not suitable for this input image. The result when using the 4x8 and the 5x8 SEs are quite similar, although the 4x8 SE is more suitable compared to the 5x8 SE after observing the output image detail. Using the 5x8 structuring element creates blurred background structures between the stack boxes and the surrounding border, as shown in Fig. 13. Therefore, this work shows that using the 4x8 rectangular SE is a suitable SE for the input image.

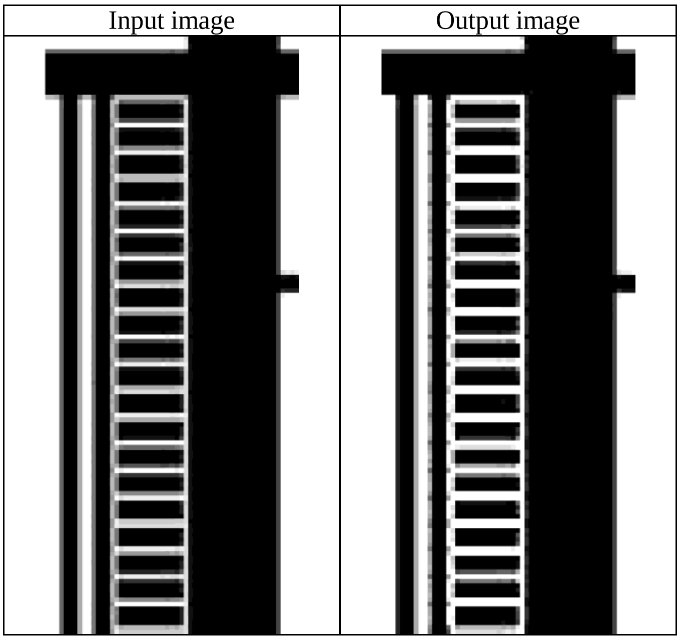

Fig. 11. Comparison between the input image and output image for the main interest part.

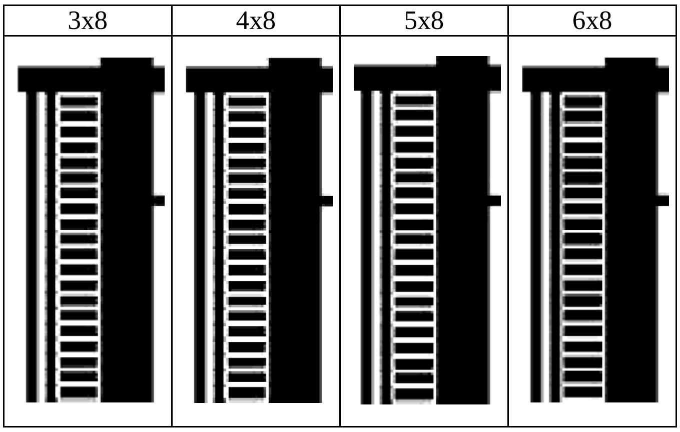

Fig. 12. Comparison of the output image using different characteristic of structuring elements.

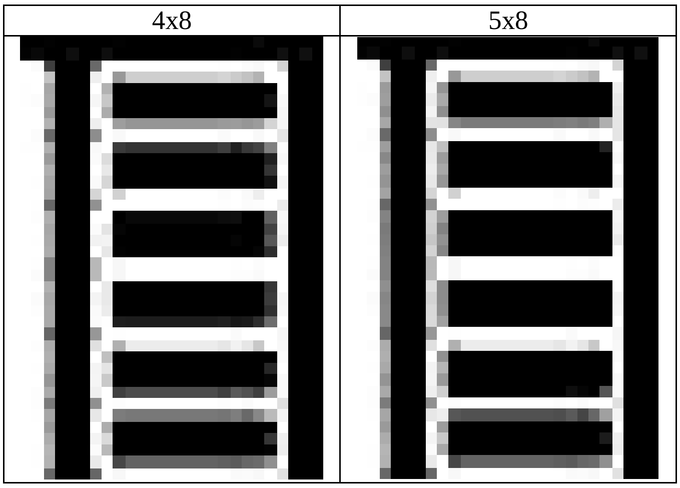

Fig. 13. Comparison between the output image using a 4x8 and 5x8 rectangular structuring element.

V. CONCLUSION

In this paper, mathematical morphological image processing provides an enhancement and improvement to the input image as the main interest information becomes much clearer than before. By applying the operations on the binary image and using several characteristics of the structuring elements with the aid of the MATLAB simulation tools, the output images can be observed and compared in order to obtain the optimum result. Therefore, the characteristic of the structuring element is an important probe in mathematical morphological operations, selecting a suitable structuring element that can provide a better morphological performance.

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