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A STUDY OF IMAGE PROCESSING USING MORPHOLOGICAL OPENING AND CLOSING PROCESSES

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Abstract: Opening and closing processes are those that manipulate the erosion and dilation processes to improve the image. Both processes depend on the characteristics of the structuring element to process the image in order to gain a better image. The opening and closing process were performed on the binary image and the erosion and dilation process was discussed. Then, a different characteristic of the structuring element was used to compare the opening and closing processes' results. As a result, the opening process removed the foreground structures that were smaller than the structuring element, while the closing process removed background structures that were smaller than the structuring element. Then, using different characteristics of the structuring element were found to affect the operations, and also mathematical morphological-image processing. Based on the results, the opening and closing processes improved the image by reducing the noise and the characteristics of the structuring element act as the important probe.

Keywords: Morphological image processing, opening, closing, MATLAB software

1. INTRODUCTION

Modern deoxyribonucleic acid (DNA) array technology was invented in the late 90s and 2000s, with the technology providing the observation of several thousands of genes simultaneously [1], [2]. In the medical field, the DNA arrays are used to observe the hybridization process of each spot on the slide. Hybridization is a process where the two samples of normal complementary DNA (cDNA) and cancerous cDNA are hybridized on the slide, and the result is the genes' expressions. Normally, the two samples will be labelled to differentiate the samples after the hybridization process [3], [4]. Later, the genes' expressions are scanned as a microarray image and processed in order to observe each spot [5]. The microarray images need to be enhanced and improved first, so that the image processing can extract the information correctly.

Gridding, segmentation, and intensity extraction is the three main stages to process the microarray image. Firstly, the gridding stage which to indicate each spot's location. Secondly, the segmentation stage which the foreground and background of the image is verified. Lastly, the intensity extraction stage is to evaluate the intensity that available on the images [6], [7]. Thus, a slight mistake at the early stage could generate an incorrect result in the end process. During the scanning process, microarray images may contain some noise and low image quality. These issues may cause incorrect information extraction [8]. Morphological opening and closing processes is one of the solutions to the enhancement of the images.

In this paper, the opening and closing image-processing algorithm will be analysed in detail using the input image in Figure 1 (a) as the study image. The effect of the structured element shape on the final output will also be studied. This is to gain further insight into how the proper choice of a structuring element is important in this image-processing algorithm. The rest of the paper is organized as follows. The literature review section discusses several applications using opening and closing

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processes in their operations. Methodology section explains the work that was done in this paper. In results and discussion section, the experimental results are observed and discussed. Finally, the last section will conclude the work based on the experimental results.

2. LITERATURE REVIEW

Magnetic Resonance Imaging (MRI) is a machine commonly used in brain imaging because it operates with a magnetic field and radio waves which generate a detailed brain image [9]. In addition, it does not emit any dangerous radiation to the surrounding area. Mathematical morphological-image processing is used on the MRI image to enhance the image's contrast. The enhancement of the image made the diagnosis easier for doctors. Not only is the image made more contrasting, but the skull is removed using the mathematical morphological-image processing. The opening operation will smooth the object image, break down the bridge and eliminate small objects, while closing will generate small breaks and eliminate small holes. By the end, the MRI image is enhanced and the skull stripping facilitates a better diagnosis of the brain image.

In paper [10], on identifying the spots on the DNA microarray image, the particular image must be enhanced and its quality improved, so that the information of that image could be extracted. Thus, mathematical morphological-image processing is used for that work. Morphological opening and closing is a method that manipulates the erosion and dilation process in order to gain image quality. Opening is a process where the image goes through the erosion and is followed by dilation, while the closing process works vice versa. The threshold of the image can provide an increase in image quality by removing certain noise from the image. If the value of the pixels is less than the threshold value, the pixels will be set to zero; having a value more than the threshold value, the pixels will be set to one. These papers investigate the images' improvement using mean squared error and the peak signal-to-noise ratio. The highest image quality will have a high value of peak signal-to-noise ratio and a low value of mean squared error.

In paper [11], scientists mostly used autonomous underwater vehicles (AUVs) to study and understand an ocean ecosystem, especially in observation of plankton. In order to do so, the Visual Plankton Recorder (VPR) was developed to record the visuals during the observation. As the visuals were recorded, the Regions of Interest (ROIs) focusing on the area where the plankton' images were mostly found are stored in the memory. The image that is stored will undergo seven processes, one of which is the morphological operation, or opening and closing process. In this case, the opening process removes the small amount of noise, while the closing process reconnects the areas that are separated by small holes. By repeating the process, clear images of plankton can be identified and the small amount of noise is reduced. Thus, the morphological operation has improved the processing speed and time in observing the plankton.

During shooting training, the automatic scoring system using the digital target image was widely used at the training site because the system reduces the processing time and can be used to record the analysis [12]. Further, the system provides better accuracy and precision of the chest-shape target image. For image processing, the input image is greyed out to enhance the stability and to improve the verification rate. After that, the morphological opening and closing processes provide good analysis of the boundaries and centre of the rings on the input image. When everything is done, the automatic scoring system can identify the location of the ring centre while giving a real-time and reliable shooting score.

In paper [13], the infrared application provided visual detection during both day and night, but the infrared image was of low visual quality. Thus, we used the morphological opening and closing operation as the proposed algorithm, and compared the linear index of fuzziness with other algorithms. Smaller values of the linear index of fuzziness show that the algorithm enhances the infrared image better than other methods. The other algorithms, including the histogram equalization algorithm (HE), the contract-limited adaptive histogram equalization algorithm (CLAHE), the multi-scale morphology-based algorithm (MSM) and the multi-scale new top-hat transform-based algorithm (MSNTH). The proposed algorithm effectively enhances the infrared images, based on the linear index of fuzziness with a value of 0.9187.

Table 1 shows the summary of the reviews of the applications that use the opening and closing method in their process. From the table, it is evident that most applications used a greyscale image as

their input image, except method [10], which used a colour image. Only methods [10], [11] and [12] used a threshold to differentiate between the background and foreground pixels. Of the five methods, method [11] has the highest complexity because the operation uses repeating morphological operations until the noise reduces. The repeating process improves the processing speed and time taken for observing. In this paper, the opening and closing processes are proposed to perform analysis of the binary image. Then, the different characteristics of the structuring element are applied in order to observe the effect on the opening and closing processes.

Table 1: Comparison of different applications

Method	[9]	[10]	[11]	[12]	[13]
Application	MRI	DNA	AUVs	Shooting training site	Visual imaging
Field	Medical	Medical	Oceanography	Military	Military
Type of image	Greyscale	Colour	Greyscale	Greyscale	Greyscale
Threshold	No	Yes	Yes	Yes	No
Accuracy	N/A	N/A	N/A	100%	N/A
Complexity	Low	Low	High	Low	Medium
Special feature	N/A	N/A	Repeating the morphological operations	N/A	N/A

3. METHODOLOGY

In this work, the morphological opening operation erodes the input image, which is then followed by dilation. Meanwhile, the morphological closing operation dilates the input image, which is then followed by erosion. In the morphological opening and closing processes, the structuring element is an important subject, as both erosion and dilation processes use the same structuring element. The morphological opening operation will remove the foreground structure that is smaller than the structuring element, while the morphological closing operation will remove the background structure that is smaller than the structuring element. Both opening and closing operations were programmed using the MATLAB software, and the operations were tested on a binary input image with the disk shaped structuring element. The morphological opening and closing performances depend on the characteristics of the structuring element.

3.1. *Input image and structuring element*

Figure 1 (a) shows the input image that is used in this paper. The image has a suitable pattern to demonstrate the opening and closing processes clearly. Further, a structuring element of a disk shape with a radius of eight pixels as shown in Figure 1 (b) is used for both processes. The structuring element is an important subject in morphological-image processing, as the characteristics of the structuring element can affect the opening and closing processes. The pixel value of one on the structuring element is set as the foreground, while the pixel value of zero is set as the background.

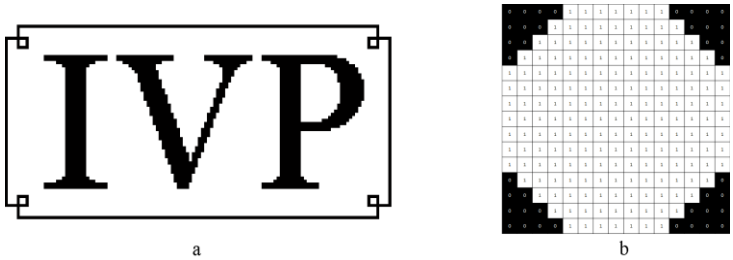

Figure 1: (a) Input image [15], (b) structuring element of a disk shape with a radius of eight pixels

3.2. *Opening and closing processes*

Together, the opening and closing processes constitute a method that manipulates erosion and dilation processes in order to gain a clearer image. Opening is a process that applies erosion and is followed by dilation on the input image (IM), while the closing process is the reverse of the opening process as shown in Figure 2. The structuring element (SE) that is used for both processes is similar. The opening and closing operations are defined as below [14]:

$$Opening = IM \ominus SE \oplus SE \quad (1)$$

$$Closing = IM \oplus SE \ominus SE \quad (2)$$

where $\ominus$ and $\oplus$ denote erosion and dilation respectively.

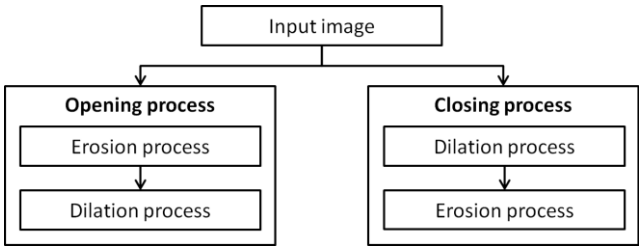

Figure 2: Flowchart of the opening and closing processes

The erosion process shrinks the foreground of the image by increasing the background area. The dilation process enlarges the foreground of the image by increasing the foreground area. Both erosion and dilation processes use the same structuring element. Different characteristics of the structuring element may affect the morphological-image processing performance of the image.

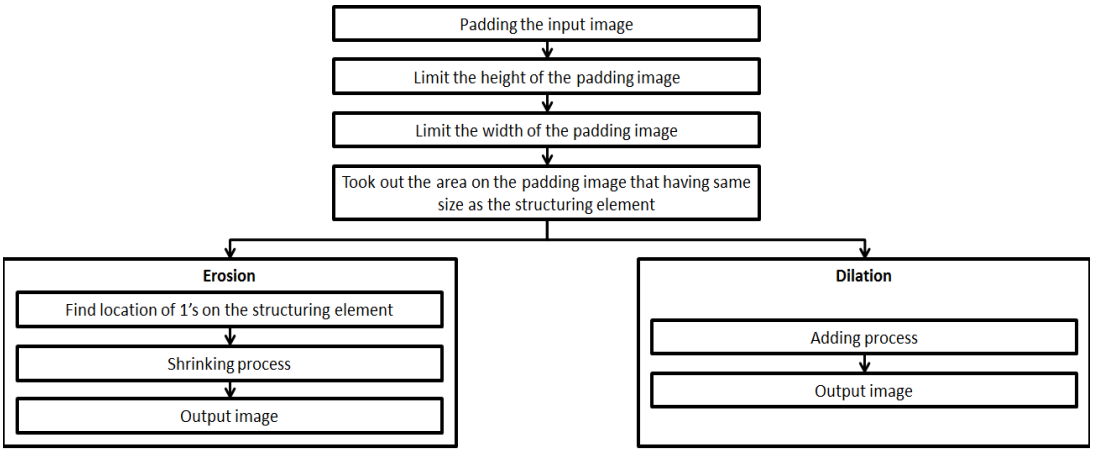

Figure 3: Flowchart of scanning process of erosion and dilation

3.3. *Erosion and dilation processes*

Figure 3 shows the flowchart of the scanning process of erosion and dilation. During the erosion, the structuring element will scan through the input image without overpass the input image. When all the locations of a pixel value of one on the structuring element overlap with the pixel value of one on particular areas of the input image, the erosion will erode that area and a value of one is set at the origin. The structuring element will scan from left to right, starting at the top left and ending at the bottom right of the input image. During the dilation, the structuring element will scan through the input image, where, at some point, the structuring element will overpass the input image. When any pixel with a value of one on the structuring element overlaps with a pixel value of one on the input image, that particular area of the image will be dilated and a value of one is set at the origin. The

structuring element will scan from left to right, starting at the top left and end at the bottom right of the input image.

4. RESULTS AND DISCUSSION

This section will discuss the experimental results of implementing the opening and closing image-processing algorithm using the test image. The opening process will be discussed first, followed by the closing process. Then we will present the results of implementing a different structuring element on the test image.

4.1. *Opening, closing, erosion and dilation processes*

Figure 4 (a) shows the results of the erosion process on an input image in which the background area increases. The erosion process is used to eliminate the foreground structures, depending on the structuring element, and this allows the foreground area to decrease as compared to the input image. Then the image undergoes a dilation process, which will increase the foreground area as shown in Figure 4 (b). The dilation process will add the foreground structures, depending on the structuring element, and this allows the foreground area to increase as compared to the previous process. Both processes leave a curved shape to the foreground and background boundaries, which are caused by using the disk shape of the structuring element. As a result of the opening process, the curve shapes are generated as shown at each corner of the image. These shapes were dependent on the characteristics of the structuring element itself.

a b

Figure 4: Opening process: the input image undergoes (a) the erosion process, which is then followed by (b) the dilation process

In the closing process, a dilation process is carried out on the input image, which causes the foreground area to increase as shown in Figure 5 (a). The dilation process adds the foreground structures to the image; as a result, the background area on the image decreases as compared to the input image. Then the image goes through the erosion process, where the image gains more background area as shown in Figure 5 (b). The erosion process is used to erode the foreground structures; as a result, the image increases the background area as compared to the previous process.

a b

Figure 5: Closing process: the input image undergoes (a) dilation process, then followed by (b) erosion process

4.2. *The characteristics of the structuring element*

In order to study the effects of the structuring element on the morphological-image processing, an experiment was carried out to compare the structuring element of a disk shape with a radius of eight

pixels, as shown in Figure 1 (b), and a structuring element of a square shape with a width of 25×25 pixels. Figure 6 shows the results of using different characteristics of the structuring element. The differences in the shape and size of the structuring element can affect the opening and closing processes. For the opening process, it is clear that each corner of the image has a different shape, resulting from using the different shapes of the structuring element. A curve shape appears when the disk shape-structuring element is applied, while a square shape appears when the square shape-structuring element is applied. For the closing process, it is evident that the different sizes of the structuring element change the results of the closing process. Using the disk shape with radius of eight pixels preserves the more object structures on the image, but using the square shape with size of 25×25 pixels eliminates much of the background area on the image. From the comparison shown in Figure 6, it can be concluded that the shape and size of the structuring element can affect the opening and closing performance. As a result, the optimum information extraction cannot be achieved.

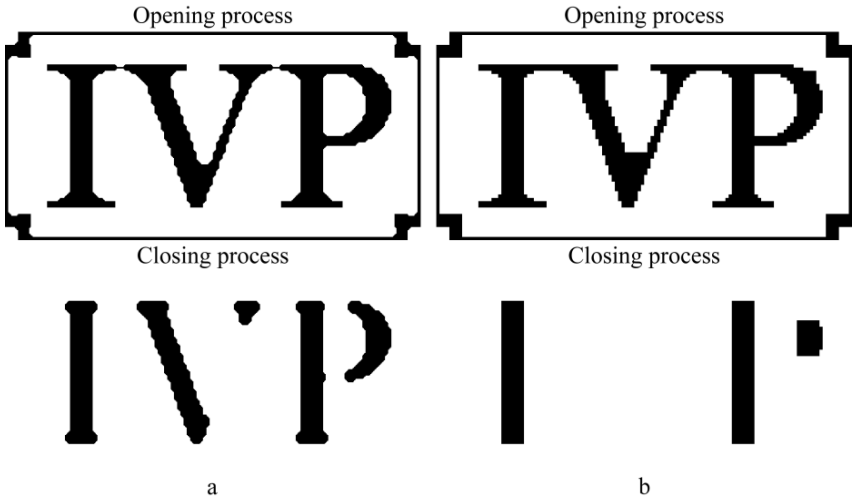

Figure 6: Comparison by using: (a) a disk shape with a radius of eight pixels, (b) a square shape with a size of 25×25 pixels

5. CONCLUSION

In this paper, the opening and closing processes proved that manipulating the erosion and dilation processes can provide an improvement of the input image. The characteristics of the structuring element play an important role in the process that can affect the whole process of mathematical morphological-image processing. The opening and closing processes used a disk shaped structuring element to test the binary image. Then, a structuring element with a different shape and size was used to compare the opening and closing processes' results. The results show that the opening and closing processes can be used to improve the image. The opening process removes the foreground that is smaller than the structuring element. The closing process removes the background structure that is smaller than the structuring element. Then, by using different characteristics, the structuring element can affect both opening and closing processes. In conclusion, the opening and closing processes are promising applications within the image-processing system, while the characteristics of the structuring element make it act as an important probe. In the future, the opening and closing processes can be tested on a different image, such as a DNA microarray image or a similar image that requires care being taken in the image-processing process.

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