Noise Removal and Enhancement of Binary Images Using Morphological Operations

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Abstract

Mathematical morphological operations are commonly used as a tool in image processing for extracting image components that are useful in the representation and description of region shape. In this paper, six basic morphological operations are investigated to remove noise and enhance the appearance of binary images. Dilation, erosion, opening, closing, fill and majority operations are tested on twenty-five images and subjectively evaluated based on perceived quality of the enhanced images. Results of the experiments showed that noise can be effectively removed from binary images using combinations of erode-dilate operations. Also, the binary images are significantly enhanced using combinations of majority-close operations.

1. Introduction

Mathematical morphology provides an approach to the processing of digital images that is based on the spatial structure of objects in a scene [11]. However, morphological techniques for digital images rely only on the relative ordering of pixel values thus they are most suitable for binary or grayscale images. Image enhancement using morphological approaches have been widely experimented in previous researches [3] [6] [8] [5] to subjectively improve the appearance of an image. Meanwhile, [12] [13] [4] [1] [2] also employed mathematical morphology operations to reduce noise existence in images.

Noise is any unwanted information that contaminates an image. The digital image acquisition process, which converts an optical image into continuous electrical signal that is then sampled, is the primary source of noise [14]. It is almost impossible to remove noise totally without distorting an image, but it is imperative that noise is reduced to a certain acceptable level for further analysis of the image. Two most common types of additive noises are Gaussian and salt-and-pepper noise. Gaussian noise normally occurs due to electronic noise in the image acquisition system, while malfunctioning pixel elements in the camera sensors, faulty memory locations or timing errors in the digitization process may cause salt-and-pepper noise [14]. Figure 1 below shows an image corrupted with Gaussian and salt-and-pepper noise, respectively.

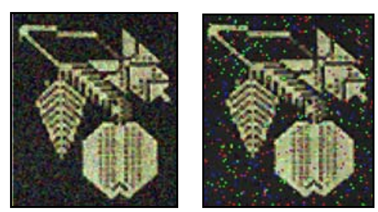

Figure 1. Gaussian vs. salt & pepper noise

2. Morphological Operations

Even though noise are ordinarily removed using spatial or frequency domain filters, morphological processing may be employed to reduce noise typically for binary or grayscale images. In this paper, six simple morphological operations are experimented to enhance and remove noise from binary images. The operations are dilation, erosion, opening, closing, fill and majority.

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2.1. Dilation

Dilation is used to add pixels at region boundaries or to fill in holes in the image [7]. In Figure 2, a dilation operation is performed on a binary image to fill in the holes in the image. A structuring element of size 3x3 is applied over the image and an OFF pixel is set to ON if any of the structuring elements overlap ON pixels of the image. The problem with using dilation is that the operation might completely closes up or narrows down holes [9]. Dilation can also be used to connect disjoint pixels and add pixels at edges. For example, the image in Figure 3 has disconnected pixels. Thus, dilation is applied to the image to link the pixels as shown in the image.

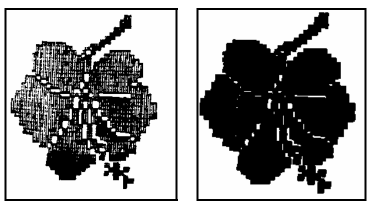

Figure 2. Using dilation to fill holes

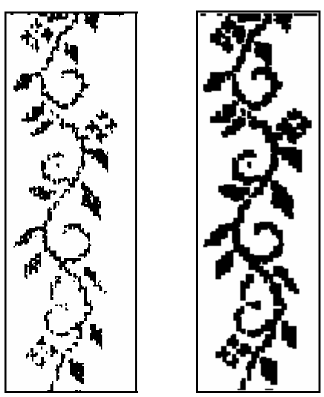

Figure 3. Joining disconnected pixels using dilation

2.2. Erosion

Erosion does the opposite operation of dilation. While dilation expands boundaries and fills holes, erosion reduces boundaries and increases size of holes. It does this by setting an ON pixel to OFF if the structuring element does not completely overlap ON-valued pixels. Figure 4 shows an example of how erosion shrinks boundaries of an image and enlarges holes. Erosion can also be used to reduce noises from an image as seen in Figure 5. [10].

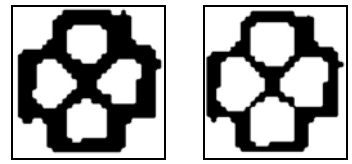

Figure 4. An eroded motif

Figure 5. Noise removal using erosion

2.3. Opening and Closing

Erosion and dilation can be performed repeatedly on an image until the desired output is produced. However, the order of the operations can make a difference to the processed image. Two common operations that combine erosion and dilation are known as opening and closing. Opening operation involves erosion followed by dilation while closing operation starts with dilation followed by erosion. Opening smoothes the contours of objects, breaks narrow joints (shown as arrow in Figure 6) and eliminates thin protrusions (shown as circle in Figure 6). Closing produces the smoothing of sections of contours but it fuses narrow breaks (shown as arrow in Figure 7), fills gaps in the contour (shown as colored circle in Figure 7) and eliminates small holes (shown as circle in Figure 7). According to [7], opening operation is used when the image has many small noise regions. Closing, on the other hand, is used to restore connectivity between close proximity objects.

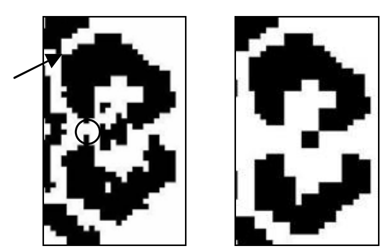

Figure 6. Open operation

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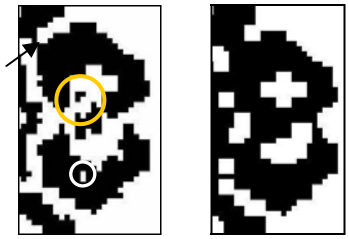

Figure 7. Close operation

2.4. Majority and Fill

Other morphological transformation may be applied on an image depending on the desired results. A pixel can be set to 1 if the majority (depending on the structuring element) surrounding neighbor pixels are 1's, otherwise it is set to 0. Isolated pixels can also be removed (set to 0) or filled (set to 1) depending on the surrounding pixels. An example of filling an isolated center pixel is shown below:

$$\begin{matrix} 1 & 1 & 1 \\ 1 & \mathbf{0} & 1 \\ 1 & 1 & 1 \end{matrix} \quad \text{becomes} \quad \begin{matrix} 1 & 1 & 1 \\ 1 & \mathbf{1} & 1 \\ 1 & 1 & 1 \end{matrix}$$

3. Performance Evaluation

The main objective of this paper is to produce the best possible representation of songket motifs in binary form. Therefore, noise removal and enhancement of these motif images are crucial to create as much as possible the exact replica of songket motifs. Songket is an exquisite hand woven cloth of the Malays made by hand weaving silver, gold and silk threads on a handloom. The beauty of songket lies in the elaborate design of the patterns and combination of motifs that are intricately woven on the cloth. Motif is the main element of designing songket patterns. When several motifs are arranged within parts of the songket, patterns are created on the songket cloth. The morphological operations: dilation, erosion, opening, closing, fill and majority operations are applied on binary motif images and subjectively evaluated based on perceived quality of the enhanced images.

4. The Experiment

The images used in this experiment are twenty-five binary songket motifs of Malaysia originating from Terengganu. These songket motifs are extracted from songket patterns and preprocessed prior to performing morphological operations.

4.1 Preprocessing

Images of the songket patterns are captured using digital camera and pre-processing processes such as motif extraction, contrast enhancement, noise filtering and binarization are applied to produce binary songket motifs. The patterns found on songket fabrics are divided into 4 compositions (Figure 8), which are patterns for *badan*, *kepala*, *pengapit* and *tepi kain*. Each of these patterns consists of several songket motifs arranged systematically based on certain rules such as chained motifs, horizontal or vertical designs or checkered. The first step in preprocessing is to allow extraction of motifs from the pattern (Figure 9).

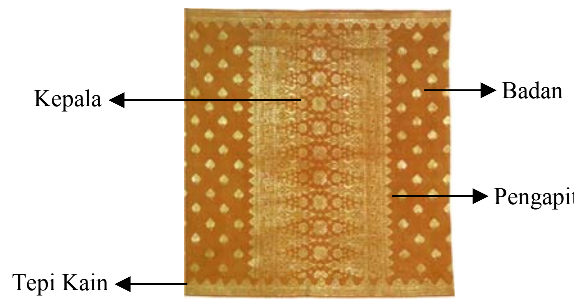

Figure 8. Songket pattern

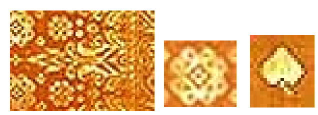

Figure 9: Extracted motifs

During the extraction process, unwanted objects or partial objects may be cropped together with the intended motif. Thus, removal of these extraneous details needs to be done by filling in the selected region of interest with the values on the boundary of the region. The motif is also converted to grayscale image for further processing. Another method used for cleaning image is by suppressing light objects connected to the image border using morphological operations. However, this method tends to reduce the overall intensity level in addition to suppressing border structure.

Contrast enhancement is important because cleaning and removing unnecessary details during pre-processing may deteriorate brightness level of the image. The pre-processed image may be subjected to histogram stretching, equalization and sliding. Histogram stretching and sliding will be based on intensity values of the input image entered by the user.

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almost impossible to remove noise totally without distorting an image, but it is imperative that noise is reduced to a certain acceptable level for further analysis of the image. This paper experimented on three different types of noise filtering: adaptive, median, and linear filters.

After noise filtering, the grayscale image is converted to binary image by thresholding. Threshold value may be chosen by the user or automatic throsholding may be done by computing a global threshold using Otsu's method. All pixels with luminance less than the threshold value is converted to 0 (black) while others will be set to 1 (white).

4.2 Morphological Processing

This paper experiments on six different morphological operations: dilation, erosion, opening, closing, fill and majority operations. Morphological operations in this paper are used for noise removal and to produce the best possible representation of the actual songket motif. All twenty-five motifs require different morphological operations in different sequences depending on the results after binarization process. Dilation is used to enlarge boundaries and closing holes, while erosion does the opposite. Opening performs erosion followed by dilation and closing, vice versa. Filling will set isolated pixels in a neighborhood of 0’s to 1. The last operation that is majority will set a pixel to 1 or 0 depending on the majority of its neighborhood pixels. Each operation may be applied repeatedly on the image to produce the best desired result. For example, an image may be subjected to dilation, erosion, majority, erosion and dilation to produce the intended result.

5. Results and Discussions

Table 1 summarizes the sequence of morphological operations applied on all twenty-five motifs. Out of the six morphological operations applied on the motif images, close is the most used operation followed by dilate, majority, erode, fill and open. Figure 10a and 10b show examples of a motif image before and after it was subjected to majority, dilate, close, fill and erode operations, respectively. As can be seen, different operations have to be applied to the image to achieve the best-desired results. In this case, majority operation is used to smooth edges of the image and its output is the best representation of the original motif.

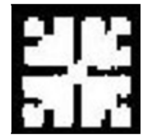

Figure 10a. Before morphological operations

Figure 10b. After majority, dilate, close, fill, erode

Table 1. Morphological operations results

Image	Morphological Operations
1.	Erode(3x), Dilate(3x), Majority-Close(4x)
2.	Erode(2x), Dilate(3x)
3.	Majority-Close(2x)
4.	Erode, Dilate
5.	Majority-Close (5x)
6.	Majority-Close
7.	Erode, Fill, Majority-Close(4x), Open
8.	Erode, Close, Dilate, Fill, Majority
9.	Dilate, Open, Dilate
10.	Majority-Close(3x), Erode
11.	Close
12.	Majority
13.	Erode(3x), Dilate(3x), Close-Majority, Close
14.	Close-Majority(3x)
15.	Close
16.	Fill
17.	Fill
18.	Fill, Erode, Dilate
19.	Majority, Erode, Dilate, Fill
20.	Majority, Erode, Dilate
21.	Erode(3x), Dilate(5x)
22.	Dilate(4x), Close
23.	Majority, Close, Dilate
24.	Majority-Close(2x)
25.	Dilate(2x), Close, Dilate

Dilation, on the other hand, enlarges the image unnecessarily. This operation is more appropriate to connect disjoint pixels of an image as shown earlier in Figure 3. Another drawback of dilation is it could

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enhance noise in the image if used incorrectly as shown in Figure 11.

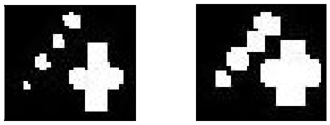

Figure 11. Noise enhanced after dilation

Similar to dilation, closing is also not apt for the original image in Figure10a. A more accurate usage of closing operation can be seen in Figure 12 (shown in circles) where tiny holes are being filled and narrow breaks are merged.

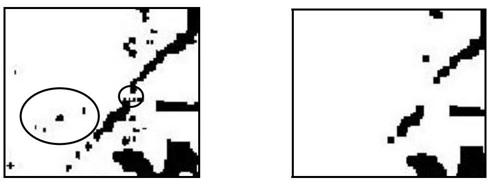

Figure 12. Closing operation

Fill operation in Figure 10b does not do any changes to the original image of Figure 10a. However, images with isolated interior pixels (as shown in circles) can be significantly improved using this operation as shown in Figure 13.

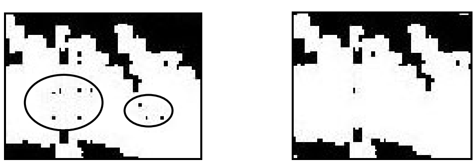

Figure 13. Fill operation

Even though each of the operation can be applied individually, combinations of two or more operations applied in sequence can substantially enhanced the motif image. For example, combinations of majority and close done in sequence will smooth edges and fill tiny holes in the image. Image 3, 5, 6, 7, 10, 14, 23 and 24 all uses the combination of close and majority to improve their appearances. Another notable combinations of operations are erode and dilate. An image that has a lot of diminutive noise speckles can be greatly enhance if erosions are done repeatedly on it, then followed by dilations to reinstate the motif shape again. Image 1, 2, 4, 13, 18, 19, 20, 21 utilize these operations to attain the best-desired appearance of the songket motif.

6. Conclusion and Future Work

The single most used morphological operations in paper are close, dilate, majority and erode. Even though on their own these operations can contribute in enhancing the motif images, combination of majority-close and erode-dilate are able to significantly improve their appearance. The primary objective of noise removal and enhancement in this paper is to reduce noise as much as possible without altering the shape of the original songket motif. The suggestions given in this paper are based on the experimental results. It can be conclude that there is not a single optimally suited method of noise removal and enhancement for all songket motif images. It is often best to experiment with the images differently to achieve the desired result that resembles the actual motif. For future work, more morphological operations such as thinning, pruning or even region filing can be added and tested in the experiments. Other than visual evaluation, numerical evaluation such as the mean-square error and correlation ratio can also be used as performance evaluation.

7. Acknowledgements

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