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A Case Study of Impulse Noise Reduction Using Morphological Image Processing with Structuring Elements

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ABSTRACT

Image enhancement plays a vital role in the field of digital image processing since the noise is added very often with the original image. Spatial filtering techniques like low pass, high pass, band pass and notch with the help of convolution mask are often used to enhance the image with reduced noise. Recently, morphological algorithms play a major role in the area of filtering noise, boundary detection, shape detection, image manipulation, etc. Especially by applying dilation, erosion, opening and closing to the image appropriately, the quality of the image can be further enhanced. In this study, morphological algorithms are being applied to remove the salt and pepper noise from the input image. Erosion followed by dilation and dilation followed by erosion are the main methods to remove this kind of impulsive noise. MATLAB software is used to apply these opening and closing methods to enhance the quality of the image with difference structuring elements. Simulation results are obtained and the comparison is done with the performance metrics like Peak Signal-to-Noise Ratio (PSNR), Mean Absolute Error (MAE), Normalized Correlation Coefficient (NCC) and Image Enhancement Factor (IEF) with different structuring elements.

Key words: Image enhancement, closing, impulse noise, morphological filtering, opening

INTRODUCTION

In the field of image processing, modern trend moves towards handling images effectively with more clarity and high performance. This image enhancement can be done either in spatial domain or in frequency domain. Low pass, high pass, band pass and notch filters are designed to remove the noise from the image or to enhance the quality of the image (Chen *et al*., 2013). If the filter or kernel size is small, filtering can be done more effectively in the spatial domain (Islam *et al*., 2010). If the kernel or convolution mask size becomes large, this would be tedious in the spatial domain. In such a case, the filtering could be done more effectively in the frequency domain. Since the convolution becomes multiplication here, the processing would be done more effectively even with large kernel size (Elamaran *et al*., 2013; Malik and Baharudin, 2012).

In some applications, there is a necessity to detect the shape and structure of the image or a pattern within an image. Morphological algorithms are more pertinent for this kind of image analysis (Li *et al*., 2013). A particular shape can be extracted and analyzed with the help of dilation and erosion processes. A particular pattern size can be enlarged by dilation and minimized by erosion. By combining both dilation and erosion, morphological filtering would be achieved. Input image can be smoothened along with the removal of noise by opening and closing. Edge detection, feature detection, image segmentation, counting objects is the other applications of morphological algorithms. These operations are not linear like spatial filtering using convolution masks (Elamaran *et al*., 2012; Dougherty, 2009).

In some applications, there is a requirement to detect internal and external boundaries of a pattern within an image. Erosion output is subtracted from the image to get an internal boundary and input image is subtracted from the dilation output to get an external boundary (Qidwai and Chen, 2009). Set theory is the most fundamental concept applied to morphological algorithms. Boolean logic operations like exclusive OR and NOT are performed to process the image. Union operator is equivalent to the OR and intersection operator is equivalent to the AND logic operation (Elamaran *et al*., 2012).

A main objective of this study is to implement morphological filtering to reduce the impulsive noise content from the given input image. Applying dilation once or twice followed by erosion and applying dilation once or twice followed by erosion are the key techniques for the task of filtering. A detailed analysis is done to use the best structuring element to remove the impulse noise from a binary image using the proposed algorithm. More appropriate Structuring Elements (SE) are chosen such a way that the noise would be reduced further.

Morphological image filtering: Morphological image processing is the best tool used for extracting or modifying information on the shape or structure of the objects within an image. Very often this would be applied to binary images and also this can be extended to gray scale images too. This is the different one from filtering in which the noise is filtered with the help of filter and the output image is obtained. But here, a kind of image analysis is performed to the given input image (Priya and Pugazhenthi, 2014).

For example, a classifier is used to convey the category of the objects in an image. In this study, morphological operations are performed to remove a salt and pepper noise from an image. So, morphological filtering task is implemented and the results are analyzed with the PSNR performance metric (Gopi, 2007). Apart from this hit or miss, thickening, thinning and skeletonization are also can be used for the purpose of image segmentation and classification. Overall, the morphological algorithms are very successful in the field of digital image processing (Tan and Jiang, 2013).

Basic morphology operations like dilation and erosion can be applied to the basic shapes png image, which is shown in Fig. 1. A salt and pepper noise is added with the original one and is used for the filtering purpose by dilation, erosion, opening and closing morphological processes with different structuring elements. A noisy image is shown by Fig. 2.

Dilation and erosion: Dilation is a process in which the structuring element is placed on the input image and if at least one pixel match with the structuring element, then the center pixel is replaced with 1. If the dilation is required in all directions or horizontally and/or vertically, the structuring elements are chosen appropriately. The size and the design of the structuring element play a vital role in the dilation process. Actually the original pattern size will be enlarged. Even to detect a boundary line of an object, this dilation could be useful. This is accomplished by dilating all directions and by subtracting the original image from the result (Russ and Russ, 2007).

Erosion is a process in which the structuring element is placed on the input image and if every pixel in a structuring element matches every pixel in the image region, the center pixel is replaced with 1. The size of the pattern is shrinking while the implementation of erosion process. If this process is repeated twice or thrice, the region of interesting pattern size will be minimized further (Marques, 2011).

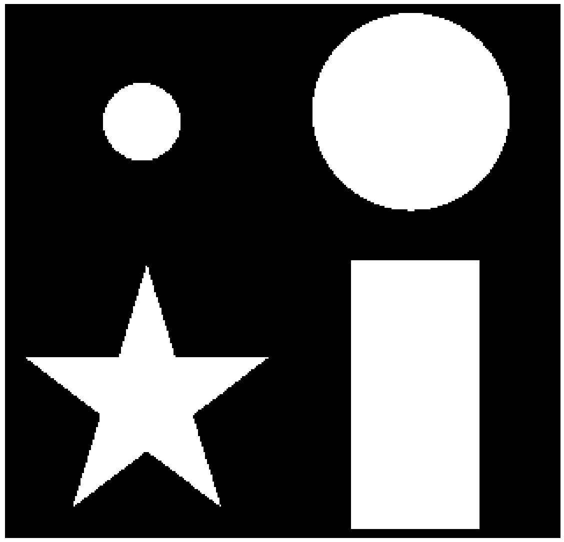

Fig. 1: Input binary image

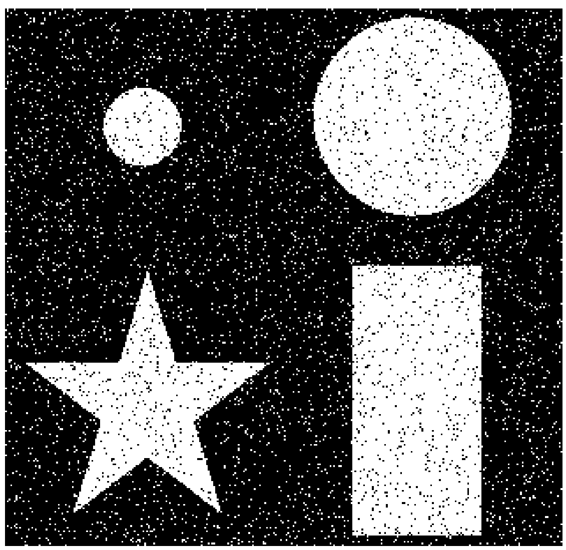

Fig. 2: Input binary image with added impulse noise

Opening and closing: The results of the dilation and dilation followed by first erosion are shown in Fig. 3 and 4, respectively. The dilation result shows that the noise involved within the object is removed completely. But the noise within the background is enlarged and this can be reduced by applying erosion.

Since the noise size is more, erosion can be applied again and again. Implementing this from hardware point of view, this algorithm make use of more resources and time consuming. But the final result would be with better quality. The equation describe these algorithmic steps applied to the input impulse noisy image A with structuring element B:

$$Y = ((((A \oplus B) \oplus B) \oplus B) \oplus B) \oplus B \quad (1)$$

Dilation followed by erosion is being referred as closing.

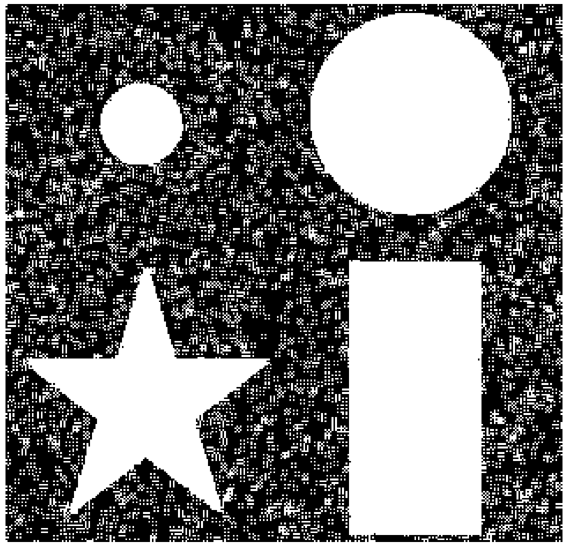

Fig. 3: Dilation applied to the noisy image

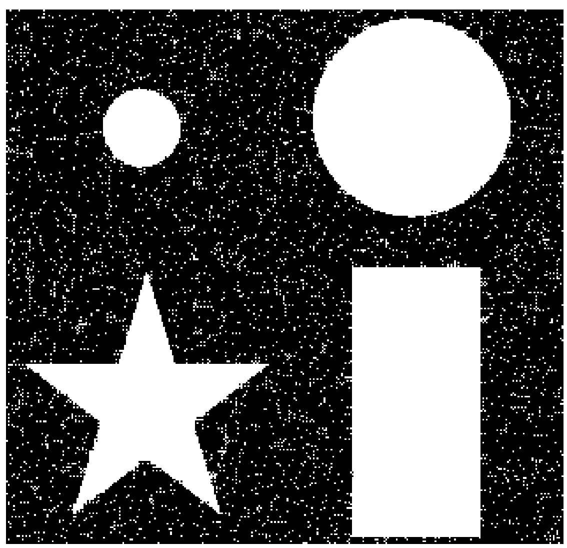

Fig. 4: Closing applied to the noisy image

PROPOSED METHODOLOGY

The methodology implemented in this study is summarized as below:

Step 1: Get an input binary image of size N×N
Step 2: Add impulse noise to the original input binary image
Step 3: Apply dilation to the noisy image
Step 4: Apply erosion the resultant image
Step 5: Apply erosion first time after closing
Step 6: Apply erosion two times after closing
Step 7: Apply erosion three times after closing and obtain the noise free image
Step 8: Repeat step 2-7 by adding different impulse noise intensities

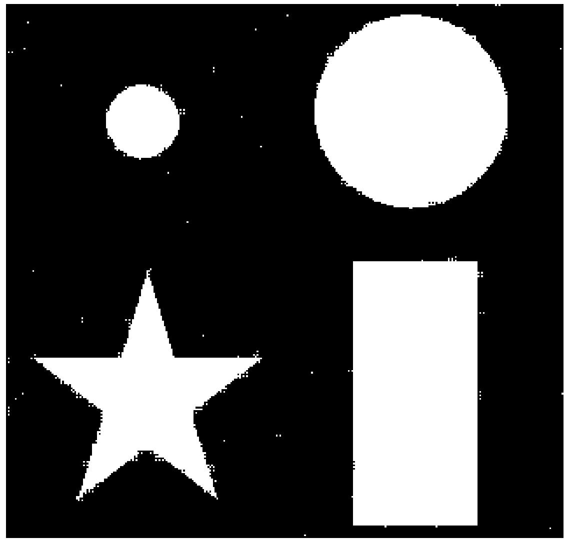

Fig. 5: Closing with first erosion using SE1

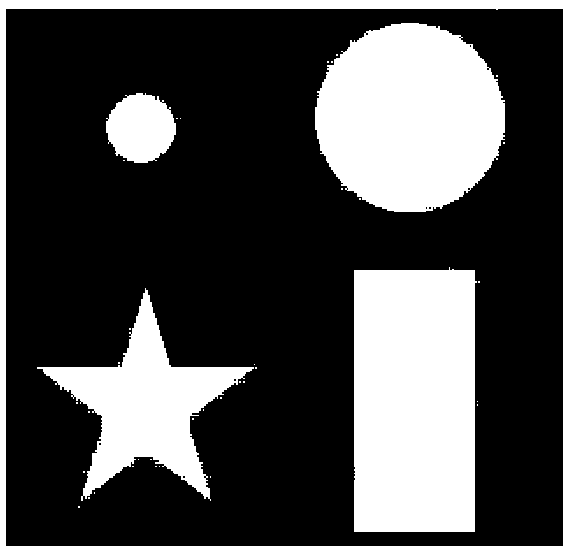

Fig. 6: Closing with second erosion using SE1

Figure 3 shows the multiple erosions followed by closing with the help of structuring element. The structuring element, SE1 used here is described as in Eq. 2. After multiple erosions, the noise content in the original image is almost removed at the cost of complexity in algorithm. First erosion, second erosion and third erosion after closing results are shown in Fig. 5-7, respectively.

The amount of dilation and/or erosion can be done with a suitable structuring element. These operations are performed with depends upon 1s and 0s in a structuring element. For example, a 3×3 structuring element with all 1s indicate the dilation is performed in all the directions. This one is expressed in the Eq. 3 as structuring element 3 (SE3). In dilation, at least one pixel match with the structuring element, then the center pixel is replaced with 1. But with the erosion process, if all the pixels in the pattern of the image match with the structuring element, then the center pixel is replaced with 1:

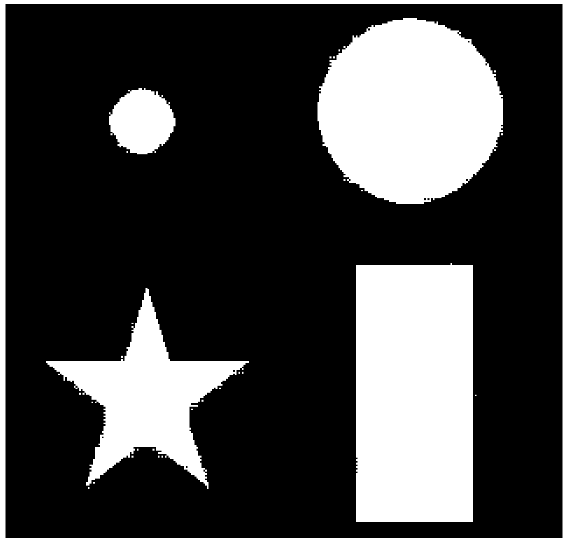

Fig. 7: Multiple erosions after closing using SE1

$$SE1 = \begin{bmatrix} 1 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 1 \end{bmatrix} \quad (2)$$

Equation 3 shows the different structuring elements used for the same algorithm to remove noise and increase the PSNR value:

$$SE1 = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{bmatrix},\ SE2 = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix},\ SE4 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (3)$$

Structuring element decides dilation and erosion process. If all the elements are 1, then the dilation takes place in all directions as in SE3. If the dilation should take place both in horizontal and vertical directions, SE2 can be used. Similarly, if the dilation is needed in only diagonal directions, the SE4 would be used. Depends on the shape of the structuring element, both closing and opening results are varied. The SE2 may does the dilation in the horizontal and vertical directions and SE4 may do the dilation diagonally. This is verified with the arrangements of 1s in those corresponding structuring elements. In spatial domain filtering, averaging filters are used to blur the image and to remove the high frequency noise contents in the image. But these filters are not good in the filtering of salt and pepper noise (Esakkirajan *et al*., 2011). A non-linear filter like median filter would be used to remove this kind of impulsive noise from the image. In spatial domain filtering to remove the salt and pepper noise with median filter, the larger size kernels are not appropriate since the median value deviates from the desired pixel. Morphological operations are not linear and are useful to remove the salt and pepper noise (Toh and Isa, 2010).

Figure 8 shows the dilation result using the structuring element SE2 and Fig. 9 indicates the final erosion using the same structuring element. Similar results are obtained using the structuring element SE3 and SE4 and the corresponding results are shown in Fig. 10-13, respectively.

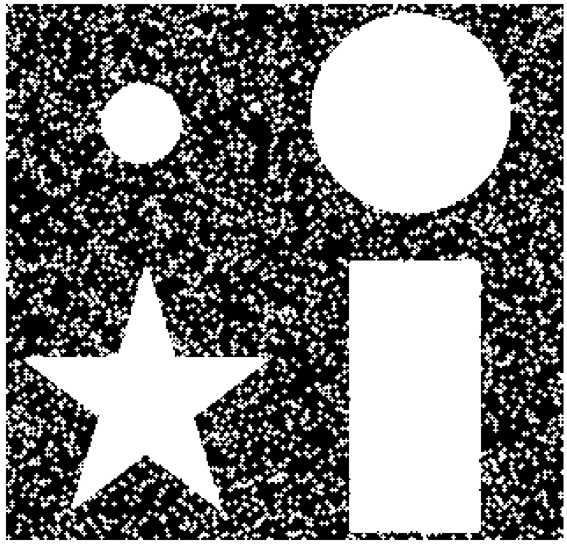

Fig. 8: Dilation using SE2

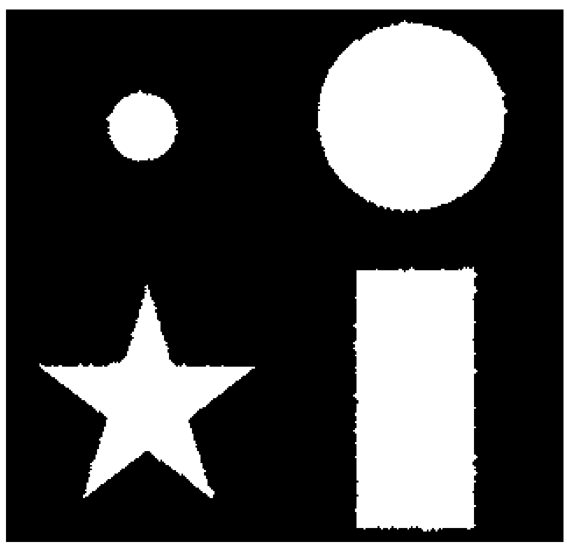

Fig. 9: Closing with multiple erosions using SE2

RESULTS AND DISCUSSION

Image enhancement algorithms are effectively implemented even using average low pass filtering, which reduce the noise content from the image but the blurring effect occurs at the resulting image. Blurring effect depends on the size of the filter; more blurring occurs with a bigger kernel size. Morphological algorithms are effectively used to remove noise too apart from the boundary detection, pattern segmentation, classification etc.

Performance metrics: Let orig (x,y) be the original noise-free image with size M×N, f (x,y) be the impulse noise added image and the f' (x,y) be the restored image with the same size:

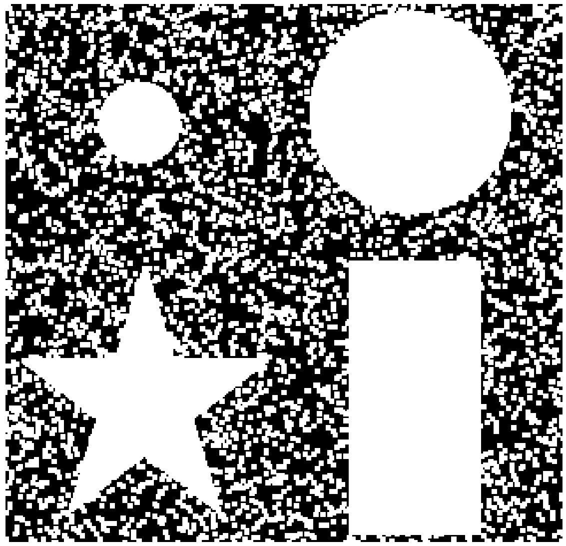

Fig. 10: Dilation using SE3

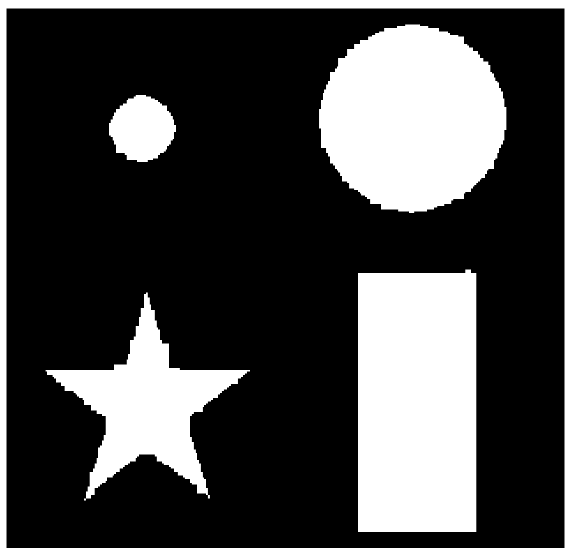

Fig. 11: Closing with multiple erosions using SE3

$$MSE = 1\frac{1}{MN}\sum_{xy}(f'(x,y)-f(x,y))^2 \quad (4)$$

$$PSNR = 10\log(\frac{255^2}{MSE}) \quad (5)$$

$$NCC = \frac{\sum_{x=1}^{M}\sum_{y=1}^{N} f(x,y)-\mu_{f(x,y)})(f(x,y)-\mu_{f(x,y)})}{\sqrt{\sum_{x=1}^{M}\sum_{y=1}^{N}(f(x,y)-\mu_{f(x,y)})^2\sum_{x=1}^{M}\sum_{y=1}^{N}(f(x,y)-\mu_{f(x,y)})^2}} \quad (6)$$

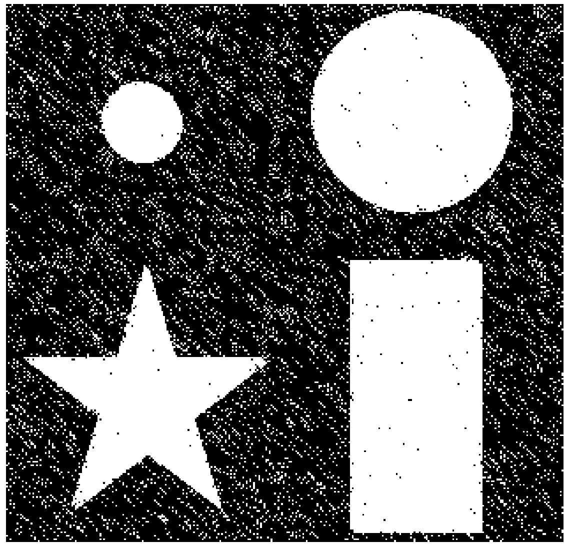

Fig. 12: Dilation using SE4

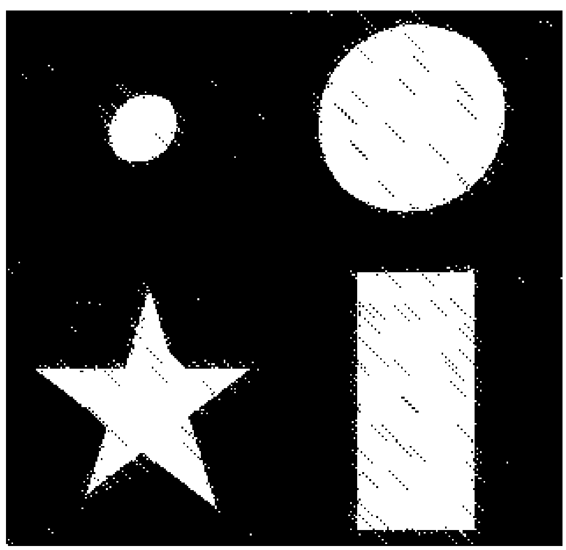

Fig. 13: Closing with multiple erosions using SE4

$$\text{IEF} = \frac{\sum_{x=1}^{M}\sum_{y=1}^{N}(\text{orig}(x,y)-f'(x,y))^2}{\sum_{x=1}^{M}\sum_{y=1}^{N}(f(x,y)-f'(x,y))^2} \quad (7)$$

where, $\mu_{f(x,y)}$ and $\mu_{f'(x,y)}$ are the mean value of the input and output images.

All the above algorithms presented here are implemented using MATLAB software tool and the performance metric results have been compared and depicted below (Melange *et al*., 2011; Hsieh *et al*., 2013). The performance metrics like PSNR, MAE, NCC and IEF are obtained using four structuring elements with 50% impulse noise intensity as shown in Table 1. It is apparent that the SE2 provides higher PSNR, smaller MAE, higher NCC and higher IEF among the other three structuring elements.

Detailed comparison analysis

PSNR: Simulation results show that the structuring element SE2 is good (high in the Fig. 14a) for PSNR metric compared with others. The structuring element SE3 is poor

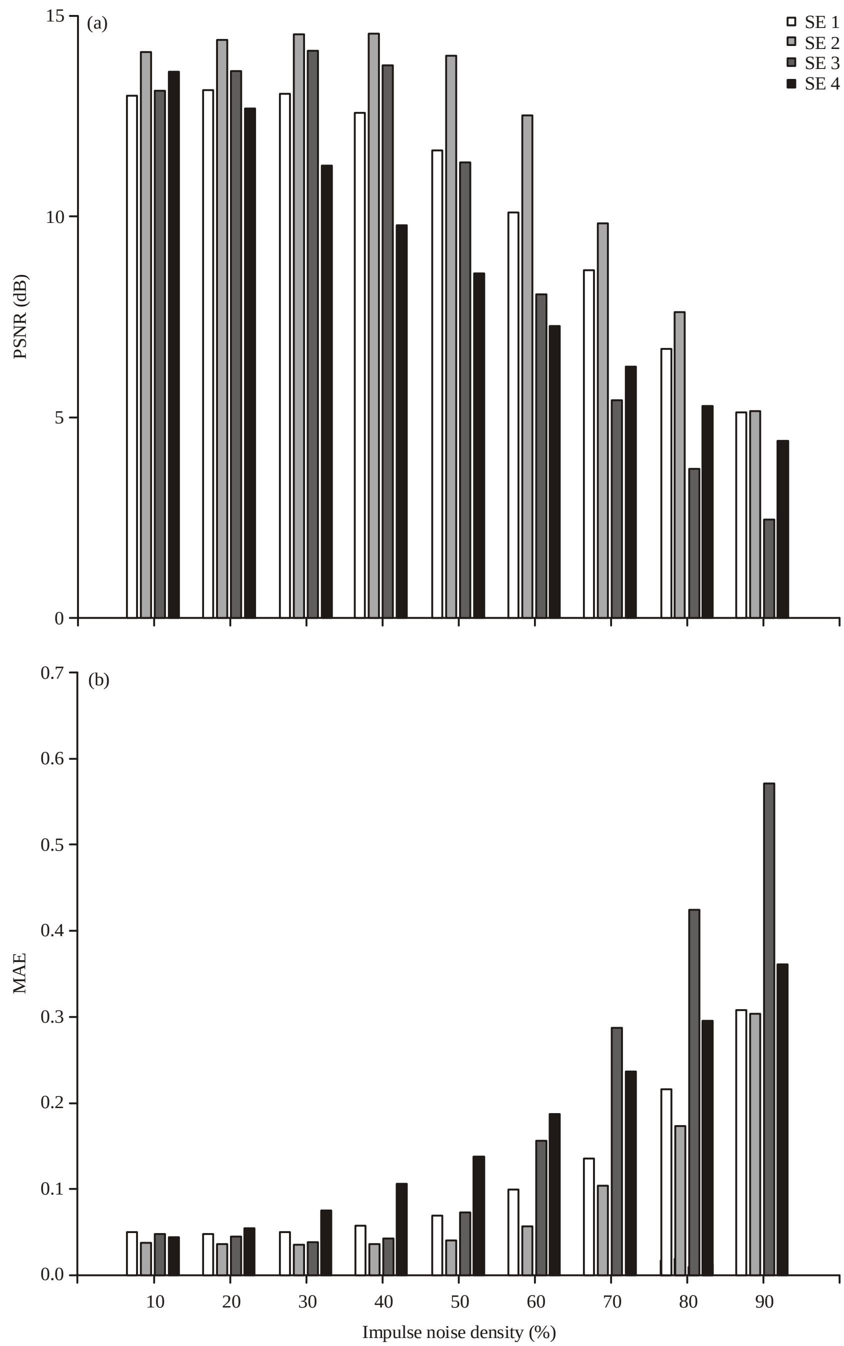

Fig. 14(a-d): Continue

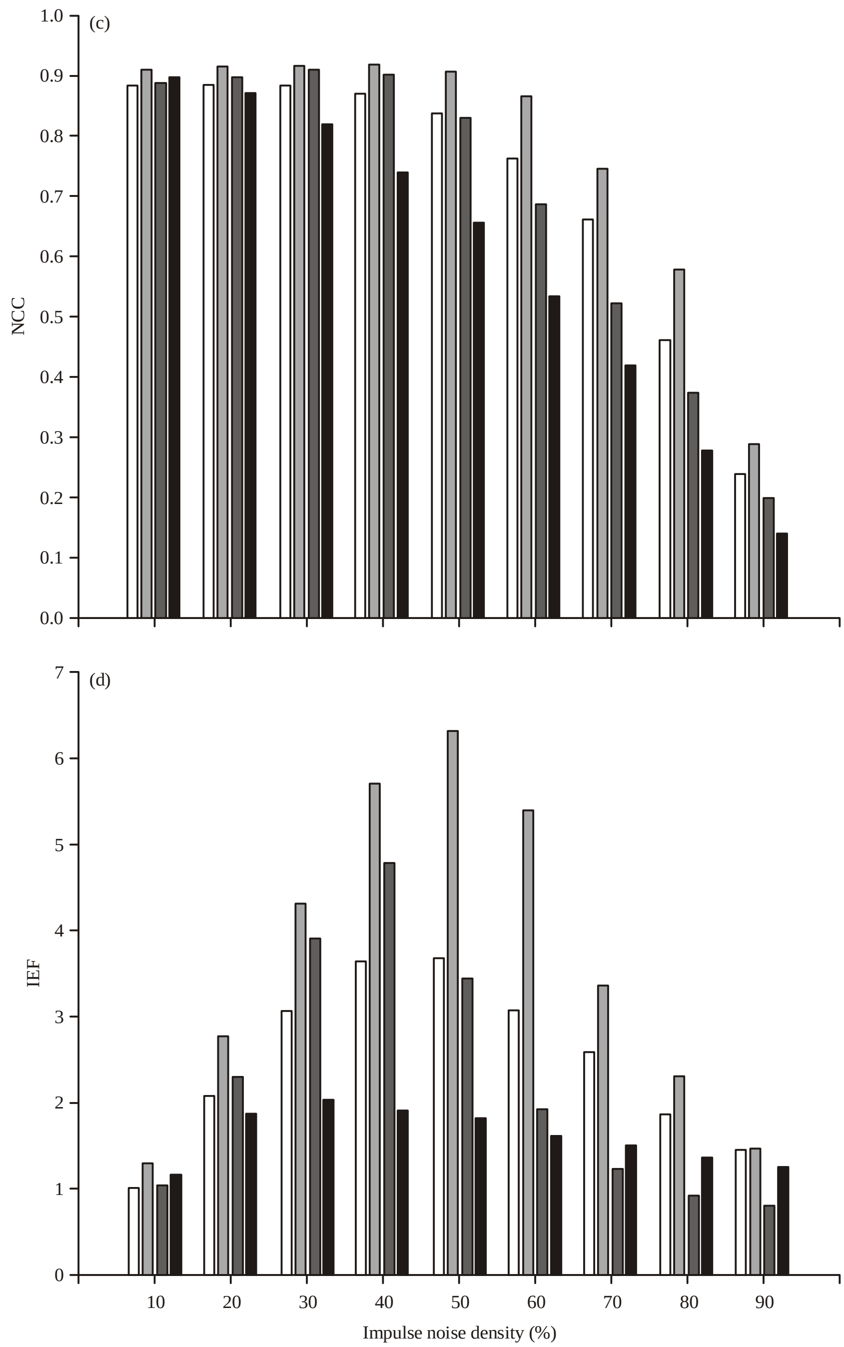

Fig. 14(a-d): Results of (a) PSNR, (b) MAE, (c) NCC and (d) IEF with various impulse noise intensities using four structuring elements

Table 1: Results of PSNR, MAE, NCC and IEF with SE1 with 50% impulse noise intensity

Structuring elements	PSNR (dB)	MAE	NCC	IEF
SE1	11.64153	0.068525	0.835078	3.669466
SE2	14.00213	0.039791	0.904777	6.319215
SE3	11.35059	0.073272	0.829128	3.431697
SE4	8.564337	0.139177	0.654609	1.806690

(low in the Fig. 14a) for 70, 80 and 90% impulse noise intensities. The structuring element SE4 is poor (low in the Fig. 14a) for 20, 30, 40, 50 and 60% impulse noise intensities.

MAE: Simulation results show that the structuring element SE2 is good (down in the Fig. 14b) for MAE metric compared with others. The structuring element SE3 is poor (high in the Fig. 14b) for 70, 80 and 90% impulse noise intensities. The structuring element SE4 is poor (high in the Fig. 14b) for 20, 30, 40, 50 and 60% impulse noise intensities.

NCC: Simulation results show that the structuring element SE2 is good (high in the Fig. 14c) for PSNR metric compared with others. The structuring element SE4 is poor (low in the Fig. 14c) for overall impulse noise intensities.

IEF: Simulation results show that the structuring element SE2 is good (high in the Fig. 14d) for IER metric compared with others. The structuring element SE3 is poor (low in the Fig. 14d) for 70, 80 and 90% impulse noise intensities. The structuring element SE4 is poor (low in the Fig. 14d) for 20, 30, 40, 50 and 60% impulse noise intensities.

CONCLUSION

Morphological algorithms are easily implemented for the impulsive noise reduction with dilation, erosion, opening and closing processes. Image enhancement, image classification, image segmentation internal and external boundary detection are the very important applications out of morphological operations. Non-linear filters like median filters are the key to remove salt and pepper noise from the input image. But this median algorithm is more complex compared to simple moving averaging filter. Set theory is the most fundamental concept for morphological operations with the image. Erosion and dilation are the most popular techniques to identify the image, classify the image, detect the line or boundary from the image, detect the shape of the object etc. This study removes the salt and pepper noise from the input image with the dilation followed by erosion twice or thrice even. The results are better at the cost complexity in the algorithm. This work can be further extended to remove the other kind of noises like white noise, flicker noise and shot noise, etc.

REFERENCES

Chen, Q., W. Gong and X. Chen, 2013. Research and design of MW-SVM image enhancement algorithm in embedded network video monitor system. Inform. Technol. J., 12: 526-529.

Dougherty, G., 2009. Digital Image Processing for Medical Applications. Cambridge University Press, Cambridge, UK., ISBN-13: 9780521860857, Pages: 459.

Elamaran, V., K. Narasimhan, G. Shiva and and P.V.M. Vijayabhaskar, 2012. Comparison of wavelet filters in image coding and denoising using embedded Zerotree wavelet algorithm. Res. J. Applied Sci. Eng. Technol., 4: 5449-5452.

Elamaran, V., K. Narasimhan, P.V.M. Vijayabhaskar and G. Shiva, 2013. Comparison of wavelet filters in hybrid domain watermarking. Res. J. Infom. Technol., 5: 393-401.

Esakkirajan, S., T. Veerakumar, A.N. Subramanyam and C.H. PremChand, 2011. Removal of high density salt and pepper noise through modified decision based unsymmetric trimmed median filter. IEEE Signal Proc. Lett., 18: 287-290.

Gopi, E.S., 2007. Algorithm Collections for Digital Signal Processing Applications using MATLAB. Springer, The Netherland, ISBN: 9781402064104, Pages: 190.

Hsieh, M.H., F.C. Cheng, M.C. Shie and S.J. Ruan, 2013. Fast and Efficient median filter for removing 1-99% levels of salt-and-pepper noise in images. Eng. Applic. Artif. Intell., 26: 1333-1338.

Islam, M.R., M.S. Sayeed and A. Samraj, 2010. Technology review: Image enhancement, feature extraction and template protection of a fingerprint authentication system. J. Applied Sci., 10: 1397-1404.

Li, J., C. Yang, H. Zhu, J. Liu and B. Cao, 2013. Segmentation algorithms for non-uniform froth image based on adaptive morphology. Inform. Technol. J., 12: 1350-1357.

Malik, F. and B. Baharudin, 2012. Median and laplacian filters based feature analysis for content based image retrieval using color histogram refinement method. J. Applied Sci., 12: 416-427.

Marques, O., 2011. Practical Image and Video Processing Using MATLAB. 1st Edn., Wiley-IEEE Press, USA., ISBN 13: 9780470048153, Pages: 696.

Melange, T., M. Nachtegael, S. Schulte and E.E.Kerre, 2011. A fuzzy filter for the removal of random impulse noise in image sequences. Image Vision Comput., 29: 407-419.

Priya, K. and D. Pugazhenthi, 2014. Salt and pepper noise removal algorithm by novel morpho filter. J. Applied Sci., 14: 950-954.

Qidwai, U. and C.H. Chen, 2009. Digital Image Processing: An Algorithmic Approach with MATLAB. CRC Press, UK., ISBN 13: 9781420079500, Pages: 314.

Russ, J.C. and J.C. Russ, 2007. Introduction to Image Processing and Analysis. CRC Press, Boca Raton, FL., USA., ISBN-13: 9780849370731, Pages: 376.

Tan, L. and J. Jiang, 2013. Digital Signal Processing: Fundamentals and Applications. 2nd Edn., Academic Press, New York, USA., ISBN-13: 9780124159822, Pages: 896.

Toh, K.K.V. and N.A.M. Isa, 2010. Noise adaptive fuzzy switching median filter for salt-and-pepper noise reduction. IEEE Signal Process. Lett., 17: 281-284.