Speckle Noise Removal and Edge Detection using Mathematical Morphology

Arpit Singhal, Mandeep Singh

Abstract— Mathematical morphology is a new subject established based on rigorous mathematical theories. In the basis of set theory, mathematical morphology is used for image processing, analyzing and comprehending. It is a powerful tool in the geometric morphological analysis and description. Noise removal and edge detection are very important pre-processing steps. For removing speckle noise nonlinear filtering techniques are better then liner filtering techniques image processing applications, at removing noise without affecting thin and small image features. One structure for designing nonlinear filters is mathematical morphology. Also the need of edge detection is to find the discontinuities in depth, discontinuities in surface orientation, changes in material properties and variations in scene illumination. Again mathematical morphological operations are used for edge detection and enhancement .This paper describes removal of speckle noise presented in images and then to obtain the useful edges in the output image obtained after noise removed using mathematical morphology.

Index Terms— Mathematical morphology, speckle noise, edge detection.

I. INTRODUCTION

Image processing is any form of signal processing for which the input is an image, such as a photograph or video frame; the output of image processing may be either an image or, a set of characteristics or parameters related to the image.

Image processing involves changing the nature of an image in order to either

1) Improve its pictorial information for human interpretation, or
2) Render it more suitable for autonomous machine perception.

The main concern is digital image processing which involves using a computer to change nature of digital images [1].

Digital image processing uses the computer algorithms to perform image processing on digital images. Noise removal and edge detection and the two most important steps in processing of any digital images for improving the information in the picture so that it can be easily understand by human and to make it suitable and readable for any machine which works on those images.

There are many traditional methods of edge detection by using edge detectors like sobel, prewitt, canny edge detectors [2] [3] and noise removal techniques like LEE [4], SRAD [5] filters which are used according to the type of noise present for digital image processing and mostly in case of speckle noise. When images are not disturbed by noises, those conventional edge detectors and filters are very ideal. However, actual images contain noises. Mathematical morphology (MM) is a new mathematical theory [6] [7] which can be used to process and analyse the images. In the MM theory, images are treated as sets and morphological transformations which derived from Minkowski addition and subtraction are defined to extract features in images [8]. Morphological filters[9][10][11] are nonlinear signal transformations that an image is probed by a structuring element which interacts with the image in order to extract useful information about the geometrical structure of the image and achieve the goal of preserving thin features while removing noise. Conventional morphological openings and closings are useful for the smoothing of gray-scale images. However, their use for image noise reduction is limited by their tendency to remove important, thin features from an image along with the noise [12]. One of the goals of enhancement for the speckle noisy images is to preserves thin features while removing speckle noise, so morphological filters with multiple structuring elements have been widely studied. Non linear filters based on Mathematical morphology are size and shape sensitive and they are found to be good in removing speckle patterns .Morphological filters use mathematical morphological operations such as opening, closing, top hat, bottom hat etc.

In this paper, a novel mathematical morphology noise removal cum edge detection algorithm is proposed to remove speckle noise of increasing standard deviation and then to preserve and obtain all the edges. For the evaluation of the performance of proposed algorithm parameters like Signal to Noise Ratio (SNR), Root Mean Square Error (RMSE)[13], Correlation of Coefficient (CoC), and Mean Structural Similarity Index Measure (MSSIM) [14]. These parameters are used to calculate the image quality of the output image obtained after speckle noise removed by proposed algorithm and help in comparing the results with that of previously used filters for speckle noise. Another parameter named edge preserving index (EPI) is used for measuring the edges preserved and detected by proposed algorithm with that of previously used edge detectors like Sobel, Prewitt and Canny.

A. Speckle Noise

Speckle noise is a granular noise that inherently exists in and degrades the quality of the active radar and synthetic aperture radar (SAR) images [3]. Images are corrupted by speckle noise that affects all coherent imaging systems.

Manuscript Received September 20, 2011.

Arpit Singhal, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala,147001,Punjab,INDIA. (E-mail: arpitsinghal2787@gmail.com)

Mandeep Singh, Asst. Prof., Department of Electrical and Instrumentation Engineering, Thapar University, Patiala, 147001, Punjab, INDIA. (E-mail: mdsingh@thapar.edu).

Within each resolution cell a number of elementary scatters reflect the incident wave towards the sensor. Due to the backscattering of coherent waves at different phases results in constructive or destructive interference of wave in a random manner. The acquired image is thus corrupted by a random granular pattern that delays the interpretation of the image content and reduces detectability of the features of interest. In medical literature also referred to as "texture", may present useful diagnostic information. It is therefore advantageous to provide a user interactive denoising method, where the degree of speckle smoothing can be tuned.

A speckle image V = $\{v_1, v_2, v_3, \ldots v_n\}$ is commonly modeled as $v_1 = f_1 \vartheta$ where $f = \{f_1, f_2, f_3 \ldots f_n\}$ is a noise-free image, and $\vartheta = \{\vartheta_1, \vartheta_2, \vartheta_3, \ldots \vartheta_n\}$ is a unit mean random field.

B. Edge detectors

Edges characterize object boundaries and are useful for segmentation registration and identification of objects in scenes. Edge points can be thought of as 4 pixel locations of abrupt gray level change. For example, it is reasonable to define edge points in binary images as black pixels with at least one white nearest neighbor. In a digital images edge detection is a technique to mark the point in image at which the luminous intensity changes sharply. Sharp changes in image include (i) discontinuities in depth, (ii) discontinuities in surface orientation, (iii) changes in material properties and (iv) variations in scene illumination. Edge detection of an image reduces significantly the amount of data and filters out information that may be regarded as less relevant, preserving the important structural properties of an image [2].

B.1 Sobel operator

Sobel operator is used in image processing techniques particularly in edge detection. The sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical and is therefore relatively inexpensive in terms of computations. The Sobel operator uses a mask to performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image [2].

B.2 Prewitt operator

Prewitt operator edge detection masks are the one of the oldest and best understood methods of detecting edges in images. Basically, there are two masks, one for detecting image derivatives in X and one for detecting image derivative in Y. To find edges, a user convolves an image with both masks, producing two derivative images (dx and dy). The strength of the edge at given location is then the square root of the sum of the squares of these two derivatives. The set of kernels is limited to 8 possible orientations; however experience shows that most direct orientation estimates are not much more accurate. On the other hand, the set of kernels needs 8 convolutions for each pixel, whereas the set of kernel in gradient method needs only 2, one kernel being sensitive to edges in the vertical direction and one to the horizontal direction[2].

B.3 Canny operator

Canny operator uses Gaussian convolution technique first to smooth the image, and then measured the gradient properties in the image by a set of Robert's cross convolution masks. It uses a filter based on the first derivative of a Gaussian, to for smoothing of image followed by the derivative of the gaussian, which is in one dimension since it is susceptible to noise present on raw unprocessed image data, so to begin with, the raw image is convolved with a Gaussian filter. The result is a slightly blurred version of the original which is not affected by a single noisy pixel to any significant degree.

II. BASIC MATHEMATICAL MORPHOLOGY OPERATIONS

Mathematical morphology is used to study geometric structure of images [5] [15] [16]. The basic idea above is to apply a structuring element to detect an image, to see whether the structuring element can be filled in the internal of the image well and to validate the validity of the method. The mathematical foundation of morphology and all languages used is set theory which is composed of a group of algebraic calculation. The four basic operations are dilation, erosion, opening and closing [17]. These basic operations are used to process binary image firstly, the basic theory is binary morphology. The binary morphology has natural extensions to Gray-scale morphology. The image which will be processed by mathematical morphology theory must be changed into set and represented as matrix.

Structuring Elements [18] are used in morphological theory, which are also represented as matrices. Structuring element is a characteristic of certain structure and features to measure the shape of an image and is used to carry out other image processing operations. The shape and size of the structuring element (SE) plays crucial role in image processing and is therefore chosen according to the condition of the image and demand of processing.

The basic mathematical morphological operations namely dilation, erosion, opening, closing are used for detecting, modifying, manipulating the features present in the image based on their shape. In the following, some basic mathematical morphological operations of gray-scale images are introduced [19] [15] [20]

Let $F(x, y)$ denote a grey-scale two dimensional image, B denoted structuring element. Dilation of a grey-scale image $F(x, y)$ by a grey-scale structuring element $B(s, t)$ is denoted by

$$(F \oplus B)(x, y) = \max\{F(x - s, y - t) + B(s, t)\} \qquad (1)$$

Erosion of a grey-scale image $F(x, y)$ by a grey-scale structuring element $B(s, t)$ is denoted by

$$(F \Theta B)(x, y) = \min\{F(x + s, y + t) - B(s, t)\} \qquad (2)$$

Opening and closing of grey-scale image $F(x, y)$ by grey-scale structuring element $B(s, t)$ are denoted respectively by

$$F \circ B = (F \Theta B) \oplus B, \qquad (3)$$

$$F \bullet B = (F \oplus B) \Theta B. \qquad (4)$$

Erosion is a transformation of shrinking, which decreases the grey-scale value of the image, while dilation is a transformation of expanding, which increases the grey-scale value of the image. But both of them are sensitive to the image edge whose grey-scale value changes obviously. Erosion filters the inner image while dilation filters the outer image. In general opening is used to remove small, bright details and leaving the overall intensity levels and larger bright features, while closing is used to remove small, dark details and leaving the overall intensity levels and dark features.

III. PROPOSED ALGORITHM

Step 1: Let X_i= OCC (I, Bi), where I is the input image and B_i is the flat structuring element where i= {1, 2, 3}.
Step 2: Let D = I- X, This will give a residual image which will contain noise as well as some features.
Step 3: Let D_med= median (D), Median filter is applied to remove noise from residual image and to extract features out of it.
Step 4: Let Y= X+D_med, where features extracted from residual image are added back.
Step 5: Let i= i+1
Step 6: Do Step 1 to Step 4
Step 7: Let i=i+1
Step 8: Do Step 1 to Step 4
Step 9: Let $T= (X_i \bullet B_1) \oplus B_1$
Step 10: Let $T_1= T-(X_i \bullet B_1)$
Step 11: Let $Z_b(x, y)$ = bothat (T_1, B_1)
Step 12: Let $Z_T(x, y)$ = tophat(T_1, B_1)
Step 13: Let $Z= Z_T - Z_b$
Step 14: Let A= imadjust (T_1+Z)
Step 15: Do threshold operation on A(x, y) to obtain edges in binary image.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

In this section, the proposed algorithm is compared with different speckle noise removing filters i.e. LEE filter and SRAD filter and edge detectors i.e. sobel, prewitt and canny edge detectors. The assessment parameters used are Signal to noise ratio (SNR), correlation, Structural similarity index (MSSIM), Root mean square error (RMSE) and Edge preserving index (EPI).

Table 1: Assessment parameters calculated before applying algorithm

Std. Dev. of noise	SNR	CoC	MSSIM	RMSE
0.3	12.034	0.9968	0.8025	3.7166
0.4	9.756	0.9826	0.7137	4.8315
0.5	8.5332	0.9628	0.6481	5.5619
0.6	7.3811	0.9391	0.5814	6.3508
0.7	6.4972	0.9056	0.5191	7.0311

Table 2: Assessment parameters calculated after applying algorithm

Std. Dev. of noise	SNR	CoC	MSSIM	RMSE
0.3	17.901	0.9979	0.9617	1.8914
0.4	17.083	0.9971	0.9452	2.0784
0.5	16.891	0.9939	0.9328	2.1248
0.6	16.47	0.994	0.9142	2.2304
0.7	16.028	0.9883	0.8851	2.3468

Table 3: Assessment parameter calculated after applying LEE filter.

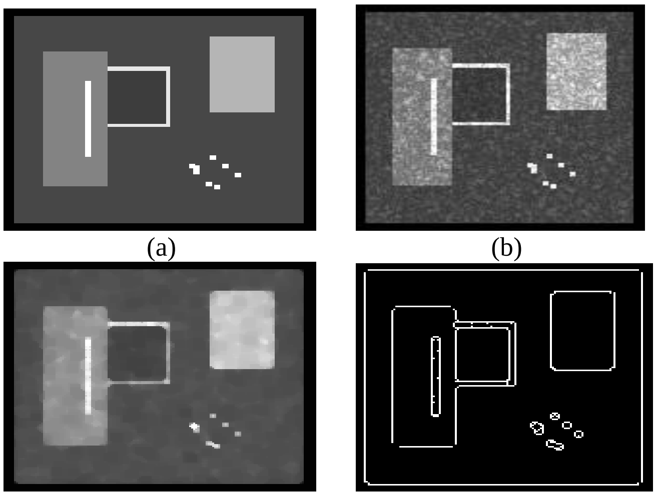
Std. Dev. of noise	SNR	CoC	MSSIM	RMSE
0.3	10.847	0.9437	0.8551	4.2609
0.4	10.178	0.943	0.8153	4.6022
0.5	9.6245	0.9413	0.7817	4.9052
0.6	8.9699	0.9398	0.7439	5.2892
0.7	8.4293	0.9303	0.691	5.6289

Table 4: Assessment parameter calculated after aaplying SARD filter

Std. Dev. of noise	SNR	CoC	MSSIM	RMSE
0.3	9.1412	0.9536	0.8969	5.1859
0.4	8.9957	0.9546	0.8931	5.2735
0.5	9.043	0.9557	0.8917	5.2448
0.6	9.0677	0.9603	0.8902	5.2300
0.7	9.1584	0.9617	0.8865	5.1756

Table 5: Assessment parameter EPI is calculated after applying proposed algorithm with different edge detectors

Std. Dev. of noise	SNR	CoC	MSSIM	RMSE
0.3	0.7130	0.0412	0.0365	0.1892
0.4	0.7156	0.0335	0.0256	0.1544
0.5	0.7097	0.0869	0.0308	0.1576
0.6	0.7158	0.0524	0.001	0.1720
0.7	0.6899	0.0567	0.0039	0.1591



(a) (b) (c) (d)

Fig. 1(a) Original Image (b) Image with speckle noise of 0.6 (c) Image after applying algorithm (d) Edges obtained after thresholding.

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication*

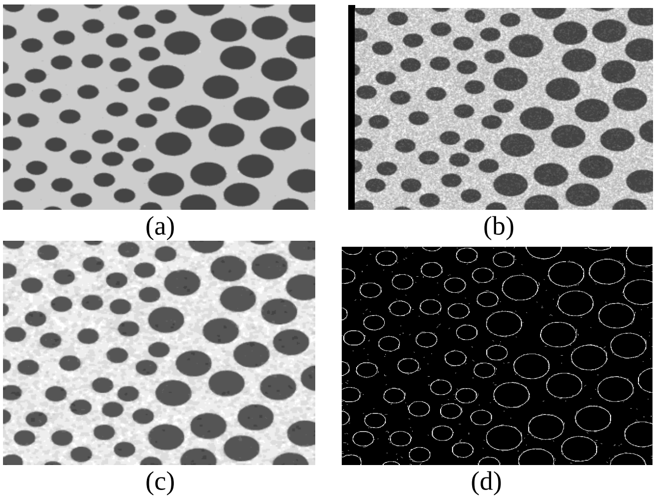


Fig.2 (a) Original Image (b) Image with speckle noise of 0.7 (c) Image after applying algorithm (d) Edges obtained after thresholding.

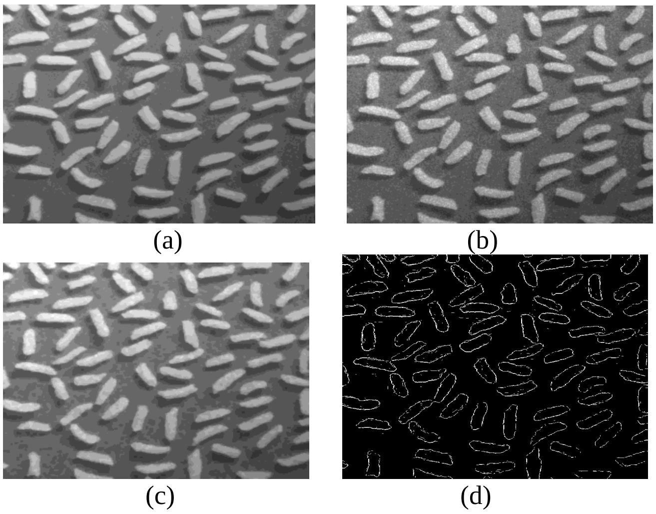


Fig. 3(a) Original Image (b) Image with speckle noise of 0.4 (c) Image after applying algorithm (d) Edges obtained after thresholding

V. CONCLUSION

In this paper, a novel mathematical morphology algorithm is proposed which is use to remove speckle noise from the image and find the edges more efficiently then the previously used edge detectors like sobel, prewitt and canny and filters used to remove speckle noise like LEE and SARD . The results are compared with different parameters and it can be seen that SNR, correlation, MSSIM and EPI are greater and RMSE is less of proposed algorithm then to already available methods.

REFERENCES

1. Rafael C. Gonzalez, Richard E. Woodes, and Steven L. Eddins, DIGITAL IMAGE PROCESSING, published by Pearson Education (Singapore) Pvt. Ltd.
2. Dr. H. B. Kekre and Ms. Saylee M. Gharge, "Image Segmentation using Extended Edge Operator for Mammography Images", *International Journal on Computer Science and Engineering,* Vol. 02, No. 04, 2010, 1086-1091.
3. Bhadauria H. S., Dewal M. L., "Comparison of edge detection Techniques on Noisy Abnormal Lung CT Image before and after Using Morphological Filter", *Published in International Journal of Advanced Engineering & Application,* Jan 2010.
4. S.Sudha,G.R.Suresh and R.Sukanesh, "Comparative Study on Speckle Noise Suppression Techniques for Ultrasound Images", *International Journal of Engineering and Technology Vol. 1, No.*, April, 2009 1793-8236.
5. Scott T. Acton, Janelle A. Molloy and Yongjian Yu, "Three-Dimensional Speckle Reducing Anisotropic Diffusion", *IEEE Conference Record of the 37th Asilomar Conference on Signals, Systems and Computers*,2003, vol. 2. p.: 1987- 1991.
6. J. Serra, Ed., ***Image Analysis and Mathematical Morphology, Vol.*** 2, ***Theoretical Advances.*** New York: Academic, 1988.
7. Maragos P., "Differential Morphology and Image Processing", *IEEE Trans Image Processing,* vol. 5, pp. 922–937, June 1996.
8. M Rama Bai, "A New Approach For Border Extraction Using Morphological Methods", *International Journal of Engineering Science and Technology,* vol. 2(8), 2010, 3832-3837.
9. Li-Hui Jiang, Zhen-Ni Jin, Fan Zhang,Rui-Hua Liu, "A New Algorithm For Speckle Suppression Using Mathematical Morphology And Adaptive Weighted Technique", *proceedings of the Sixth International Conference on Machine Learning and Cybernetics, Hong Kong*,19-20 August 2007.
10. T.Ratha Jeyalakshmi and K.Ramar, "A Modified Method for Speckle Noise Removal in Ultrasound Medical Images", *International Journal of Computer and Electrical Engineering,* Vol. 2, No. 1, February, 2010 1793-8163.
11. Ahmed S. Mashaly, Ezz Eldin F. AbdElkawy, Tarek A. Mahmoud, "Speckle Noise Reduction in SAR Images using Adaptive Morphological Filter", *10th International Conference on Intelligent Systems Design and Applications*, 2010.
12. Richard Alan Peters, "A New Algorithm for Image Noise Reduction Using Mathematical Morphology", *IEEE Transaction on Image processing* .vol. 4. NO.5. MAY 1995.
13. M. N. Nobi and M. A. Yousuf, "A New Method to Remove Noise in Magnetic Resonance and Ultrasound Images", *Journal Of Scientific Research*, 3 (1), 81-89 (2011).
14. Chaofeng Li1,2 and Alan C. Bovik, "Three-Component Weighted Structural Similarity Index", *SPIE, 7242-24 V. 1 (p.1 of 9),* 2008.
15. Zhao Yuqian, Gui Wei-hua, Chen Zhencheng, Tang Jing-tian, and Li Ling-yun., "Medical Images Edge Detection Based on Mathematical Morphology", *", Proceedings of the IEEE Engineering in Medicine and Biology 27th Annual International Conference Shanghai, China,* PP: 6492 – 6495, 2005.
16. Yuqian Zhao, Weihua Gui and Zhencheng Chen, "Edge Detection Based on Multi-Structure Elements Morphology", *Proceedings of the 6th World Congress on Intelligent Control and Automation Dalian, China*, vol.-2, PP: 9795 – 9798, 2006.
17. M Rama Bai , Dr V Venkata Krishna and J SreeDevi, "A new Morphological Approach for Noise Removal cum Edge Detection", *IJCSI International Journal of Computer Science Issues*, Vol. 7, Issue 6, November 2010.
18. J.-A. Jiang, C.-L. Chuang, Y.-L. Lu and C.-S. Fahn, "Mathematical-morphology-based edge detectors for detection of thin edges in low-contrast regions", *The Institution of Engineering and Technology*,2007.
19. Deng Shiwei and Yuan Baozong, "Range Image Segmentation Using Mathematical Morphology", *IEEE Region 10 Conference on TENCON* Proceedings on *Computer, Communication, Control and Power Engineering,* vol-2, PP: 1009-1011, 1993.
20. Xueshun Wang, Dawei Qi and Yuanxiang Li, "Edge Detection of Decayed Wood Image Based on Mathematical Morphological Double Gradient Algorithm", *Proceedings of the IEEE International Conference on Automation and Logistics Qingdao, China*, September 2008.

AUTHORS PROFILE

Arpit Singhal, Research Scholar in Electrical & Instrumentation Engineering department at Thapar University Patiala.

Mandeep Singh is Asst. Prof. Electrical & Instrumentation Engineering department at Thapar University Patiala. He is Member of IEEE and his research areas are Bio-Medical Signal processing and Embedded systems. He has over 10 years of experience in Academia and Industry.