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 than the linear filtering techniques. The linear filtering techniques use basic linear operations such as averaging, Gaussian filtering, etc. In nonlinear filtering, some nonlinear operations are used like erosion, dilation, opening, closing, top hat, bottom hat etc. These operations are size and shape sensitive and they are found to be good in 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 preserve 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.

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 understood 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. The 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.

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.
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Within each resolution cell a number of elementary scatterers 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 \( v_i = f_i \Phi \) where \( f = \{ f_1,f_2,f_3,\ldots,f_n \} \) is a noise-free image, and \( \Phi = \{ \Phi_1, \Phi_2, \Phi_3,\ldots, \Phi_a \} \) 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 perform 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 image derivatives in \( X \) and one for detecting image derivative in \( Y \) are introduced [19] [15] [20].

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

\[
(F \ast B)(x, y) = \max \{ F(x-s, y-t) + B(s, t) \}
\]

(1)

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

\[
(F \circ B)(x, y) = \min \{ F(x+s, y+t) - B(s, t) \}
\]

(2)

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

\[
F \circ B = (F \ast B) \circ B
\]

(3)

\[
F \bullet B = (F \ast B) \bullet B
\]

(4)

Erosion is a transformation of shrinking, which decreases the grey-scale value of the image, while dilatation 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 \( X_i = \text{OCC}(I, B_i) \), 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 \( D_{\text{med}} = \text{median}(D) \). Median filter is applied to remove noise from residual image and to extract features out of it.

Step 4: Let \( Y = X + D_{\text{med}} \), 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 \( T = (X_i \cdot B_1) \oplus B_1 \)

Step 10: Let \( T_1 = T - (X_i \cdot B_1) \)

Step 11: Let \( Z_b(x, y) = \text{bothat}(T_1, B_1) \)

Step 12: Let \( Z_T(x, y) = \text{tophat}(T_1, B_1) \)

Step 13: Let \( Z = Z_T - Z_b \)

Step 14: Let \( A = \text{imadjust}(T_1 + Z) \)

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

<table>
<thead>
<tr>
<th>Std. Dev. of noise</th>
<th>SNR</th>
<th>CoC</th>
<th>MSSIM</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>12.034</td>
<td>0.9968</td>
<td>0.8025</td>
<td>3.716</td>
</tr>
<tr>
<td>0.4</td>
<td>9.756</td>
<td>0.9826</td>
<td>0.7137</td>
<td>4.831</td>
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<tr>
<td>0.5</td>
<td>8.5332</td>
<td>0.9628</td>
<td>0.6481</td>
<td>5.561</td>
</tr>
<tr>
<td>0.6</td>
<td>7.3811</td>
<td>0.9391</td>
<td>0.5814</td>
<td>6.350</td>
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<tr>
<td>0.7</td>
<td>6.4972</td>
<td>0.9056</td>
<td>0.5191</td>
<td>7.031</td>
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</table>

Table 2: Assessment parameters calculated after applying algorithm

<table>
<thead>
<tr>
<th>Std. Dev. of noise</th>
<th>SNR</th>
<th>CoC</th>
<th>MSSIM</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>17.901</td>
<td>0.9979</td>
<td>0.9617</td>
<td>1.8914</td>
</tr>
<tr>
<td>0.4</td>
<td>17.083</td>
<td>0.9971</td>
<td>0.9452</td>
<td>2.0784</td>
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<tr>
<td>0.5</td>
<td>16.891</td>
<td>0.9939</td>
<td>0.9328</td>
<td>2.1248</td>
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<tr>
<td>0.6</td>
<td>16.47</td>
<td>0.994</td>
<td>0.9142</td>
<td>2.2304</td>
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<tr>
<td>0.7</td>
<td>16.028</td>
<td>0.9883</td>
<td>0.8851</td>
<td>2.3468</td>
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</table>

Table 3: Assessment parameters calculated after applying LEE filter.

<table>
<thead>
<tr>
<th>Std. Dev. of noise</th>
<th>SNR</th>
<th>CoC</th>
<th>MSSIM</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>10.847</td>
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<td>0.8551</td>
<td>4.2609</td>
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<tr>
<td>0.4</td>
<td>10.178</td>
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<td>0.8153</td>
<td>4.6022</td>
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<tr>
<td>0.5</td>
<td>9.6245</td>
<td>0.9413</td>
<td>0.7817</td>
<td>4.9052</td>
</tr>
<tr>
<td>0.6</td>
<td>8.9699</td>
<td>0.9398</td>
<td>0.7439</td>
<td>5.2892</td>
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<tr>
<td>0.7</td>
<td>8.4293</td>
<td>0.9303</td>
<td>0.691</td>
<td>5.6289</td>
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</table>

Table 4: Assessment parameters calculated after applying SRAD filter

<table>
<thead>
<tr>
<th>Std. Dev. of noise</th>
<th>SNR</th>
<th>CoC</th>
<th>MSSIM</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>9.1412</td>
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<td>0.8969</td>
<td>5.1859</td>
</tr>
<tr>
<td>0.4</td>
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<td>0.9546</td>
<td>0.8931</td>
<td>5.2735</td>
</tr>
<tr>
<td>0.5</td>
<td>9.043</td>
<td>0.9557</td>
<td>0.8917</td>
<td>5.2448</td>
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<tr>
<td>0.6</td>
<td>9.0677</td>
<td>0.9603</td>
<td>0.8902</td>
<td>5.2300</td>
</tr>
<tr>
<td>0.7</td>
<td>9.1584</td>
<td>0.9617</td>
<td>0.8865</td>
<td>5.1756</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Std. Dev. of noise</th>
<th>SNR</th>
<th>CoC</th>
<th>MSSIM</th>
<th>RMSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>0.7130</td>
<td>0.0412</td>
<td>0.0365</td>
<td>0.1892</td>
</tr>
<tr>
<td>0.4</td>
<td>0.7156</td>
<td>0.0335</td>
<td>0.0256</td>
<td>0.1544</td>
</tr>
<tr>
<td>0.5</td>
<td>0.7097</td>
<td>0.0869</td>
<td>0.0308</td>
<td>0.1576</td>
</tr>
<tr>
<td>0.6</td>
<td>0.7158</td>
<td>0.0524</td>
<td>0.001</td>
<td>0.1720</td>
</tr>
<tr>
<td>0.7</td>
<td>0.6899</td>
<td>0.0567</td>
<td>0.0039</td>
<td>0.1591</td>
</tr>
</tbody>
</table>

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


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