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Noise Reduction Technique in Synthetic Aperture Radar Datasets using Adaptive and Laplacian Filters

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ABSTRACT

Presence of salt and pepper noise in Synthetic Aperture Radar (SAR) raw image datasets of coastal and sea areas makes it very difficult to detect the targets in it. Adaptive filters are known for their remarkable filtering of those signals which are a result of unknown terrain mapping and which has a non-stationary surface. Whereas a Laplacian filter is known for its edge marking and enhancing the processed image. Hence both the filters were used together to produce an enhance image having target with clear boundaries. The processed image has a substantial reduction in the value of salt and pepper noise. The computing power used in this filtering technique is very less as compared to other filtering methods and the results obtained are better than other methods. The position of the target can be calculated afterwards by measuring the centroid of the geo-referenced image.

***Keywords* –** SAR, Laplacian Filter, Adaptive Filter, Enhance, Image enhancement technique

I. INTRODUCTION

An image can be represented as a function of $f(x,y)$ where (x,y) are spatial (plane) coordinates. The amplitude of the function $f(x,y)$ gives the intensity of image at coordinates (x,y). Images provided by SAR systems have very high resolution and are of wide area, hence sub images or regions of interest are carved out from the original image. As an image is nothing but a matrix, hence it is easy to extract a sub image from an original image matrix. After the sub images have been extracted the noise can be removed from them using an adaptive filter first and then a Laplacian filter to enhance the target position. The noise present in the SAR dataset is due to high amount of backscatter from the sea surface [1] The waves having crust and trough produce the noise known as salt and pepper noise and it makes the detection of actual target i.e. ship very difficult. A digital filter is a system which uses certain mathematical operations to reduce or discretize certain aspects of the input data which is noise in the case of SAR dataset. Every signal processing system has a filter to its core and it helps remove noise, unnecessary clutter data and enhance the final image. The adaptive filter is a special type of filter which adapts itself according to the characteristics of the image and removes the noise accordingly [2]. Adaptive noise smoothing filter for images with signal-dependent noise [5] whereas Laplacian filter is used to mask the resultant image from adaptive filtering and then remove the remaining noise and enhancing the target object [3].

1.1. Filters

1.1.1. Averaging Filter

Averaging filter replaces each element of image matrix (pixel value) with average of pixels in a square window surrounding pixel. In a large window of operation it can remove noise more effectively but it blurs the details. Instead of averaging all pixel values in an image matrix, closer pixels can be given higher weighting and far away pixels can be given lower weighting [4].
The function for a weighted averaging filter can be given as:

$$g(m,n) = \sum_{l=-L}^{L} \sum_{k=-L}^{L} h(k,L)S(m-k,n-l)$$

Where $g(m,n)$ is output image, $h(k,L)$ is the transfer function or the weight given to an element and $S(m-k,n-l)$ is the input image.

1.1.2. Adaptive Filter

An Adaptive filter is a linear filters which is capable of changing their behavior depending upon the region of the image being filtered. These are special type of filters which are applied on the images where image characteristics vary drastically form point to point [2]. An adaptive filter is as follows:

$$g(x,y) = f(x,y) - (\sigma_n^2/\sigma_l^2) * (f(x,y) - m(x,y))$$

Where $f(x,y)$is the input image, $g(x,y)$ is the output, $m(x,y)$ is the mean image value, σ_n *and* σ_l are constants with value respectively 4 and 3. The adaptive filter given above is known as Willis filter and used in the image processing of non-stationary surfaces and targets [4].

Laplacian Filter Algorithm

Laplacian of an image $f(x,y)$ can be denoted as $\nabla^2 f(x,y)$ and expressed as

$$\nabla^2 f(x,y) = \frac{\partial^2 f(x,y)}{\partial x^2} + \frac{\partial^2 f(x,y)}{\partial y^2}$$

Digital approximation of second derivative can be done in two ways. According to the first method

$$\frac{\partial^2 f(x,y)}{\partial x^2} = f(x+1,y) + f(x-1,y) - 2f(x,y)$$
$$\frac{\partial^2 f(x,y)}{\partial y^2} = f(x,y+1) + f(x,y-1) - 2f(x,y)$$

The above expression can be realized at all the elements of an image by convolving the image with following spatial mask

$$\begin{bmatrix} f(x-1,y-1) & f(x,y-1) & f(x+1,y+1) \\ f(x-1,y) & f(x,y) & f(x+1,y) \\ f(x-1,y+1) & f(x,y+1) & f(x+1,y+1) \end{bmatrix}$$

Or

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

Another approach of digital second derivatives takes into account of diagonal elements and can be implemented as

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Enhancement of the image using Laplacian filter is based on following equation

$$g(x,y) = f(x,y) + c[\nabla^2 f(x,y)]$$

Where $\nabla^2 f(x,y)$ is the filter mask, $f(x,y)$ is the input image, $g(x,y)$ is the output image and the value of c is 1 when center coefficient of filter mask is positive and -1 when center coefficient is negative [5].

II. METHODOLOGY

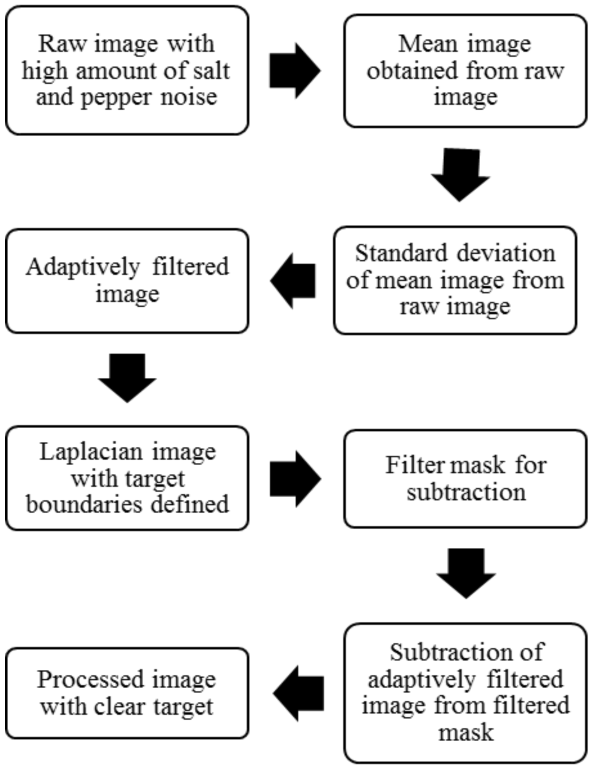

Figure 1: Flow Chart for Noise Reduction Technique And Methodology

Figure 1 shows the methodology of the research work to obtain the final image which contains a clear target with defined boundaries. At first the noise present in the raw image is smoothed out using an adaptive filter. Due to the filter target gets blurred which is not intended. To reduce this blur and produce a clear image, a Laplacian filter is then used to produce a boundary mask which is when subtracted from adaptively filtered image produces an enhanced and clear image of the target.

III. RESULTS

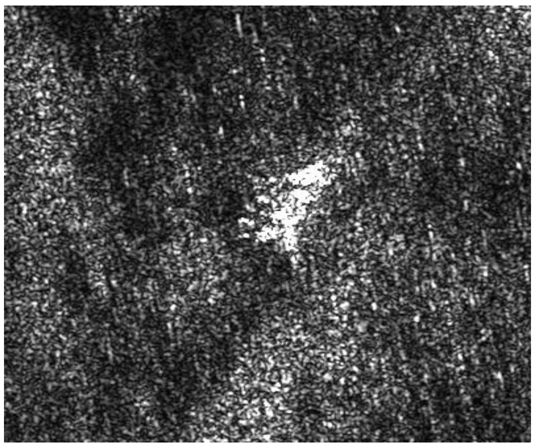

Figure 2: Original Raw Image

The raw image of the region of interest obtained from TERRASAR-X is shown in Fig. 2. It is clearly visible that the presence of noise (because of sea backscatter), has made the target very less identifiable. This noise is also known as salt and paper noise and it is induced because of the sea surface movements. To remove the noise a systematic approach of filtering was used in which an adaptive filter was first used to suppress the noise elements present in the raw image data and then the image was enhanced using Laplacian filter. The histogram of original image in Fig 3 displays the gray level value of pixel in x axis and pixel count containing that gray level value in y axis.

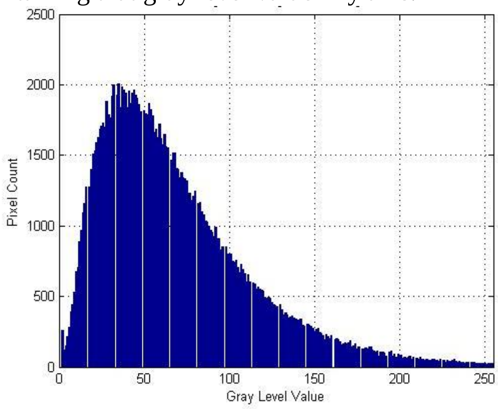

Figure 3: Histogram of Original Image

The mean image is the generated from the original image to smooth out the noise elements however in this process some details get blurred. To get a mean image each element is replaced by the mean value of its surrounding MXM matrix which is in this case matrix of 5X5 matrix. The resultant image thus produced is shown in Fig 4.

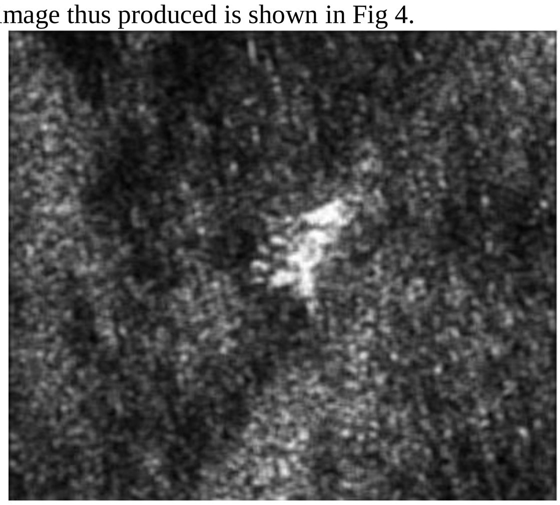

Figure 4: Resultant Mean Image

The loss of clear edges and induction of blur can be clearly seen between original and the local mean image. The histogram of the mean image shows the clear difference between the gray level value and pixel count from the original image.

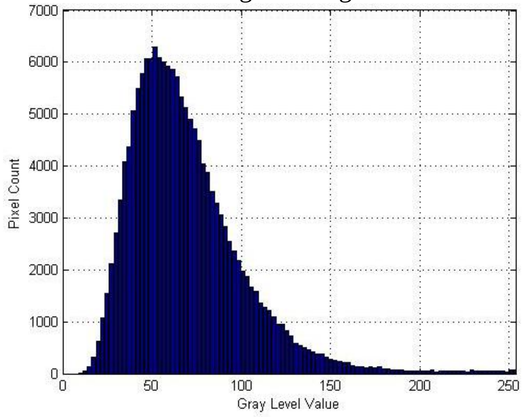

Figure 5: Histogram of Local Mean Image

After the mean image has been obtained another image showing standard deviation from the original image is obtained which is only used to find out maximum possible value of grey level of the target. From Fig 5, it can be seen that now the grey level value of majority of pixels have been shrunk to the region 10 to 100.

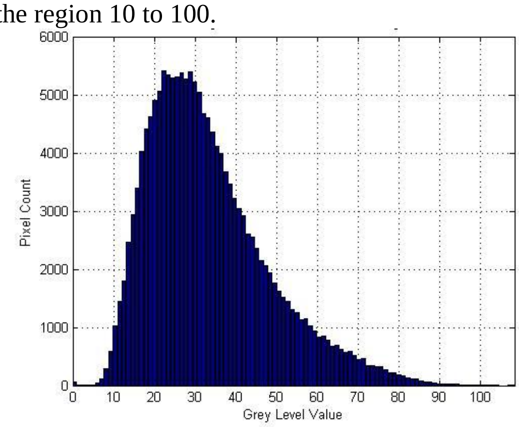

Figure 6: Histogram of Standard Deviation Image

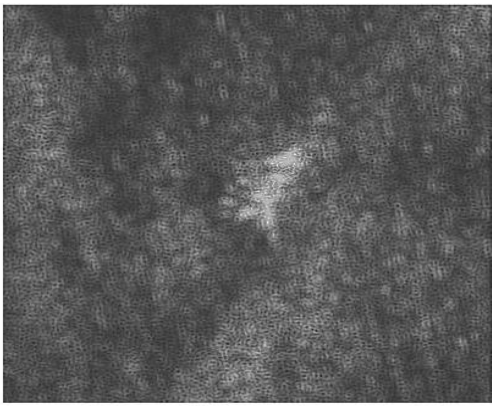

Figure 7: Result Obtained From Adaptive Filtering Technique

The histogram of standard deviation image is shown in Fig 6. It can be clearly seen that the pixels have been even further shrunk to the grey level value ranging between 10 to 70. This will help us derive the final filtered image as shown in Fig 7 which is shown below with its histogram. In the final filtered image, the histogram has been spaced between 40 to 100 giving a clear region of target as shown in Fig 8. Rest of the noise has been reduced to a minimum level, which will be masked by a laplacian filter and then will be removed by subtracting it from the original image.

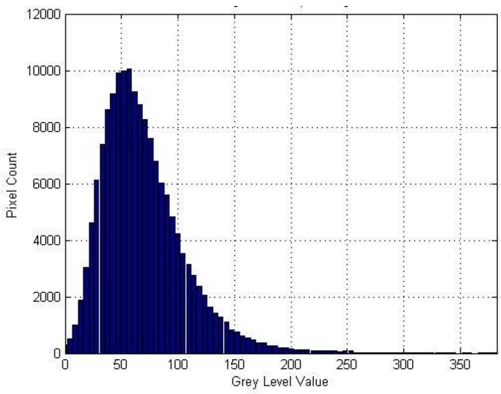

Figure 8 : Histogram of Adaptively Filtered Image

After the final filtered image has been achieved, a laplacian filter is used to mask the remaining noise and target as shown in Fig 10. The mask creates the boundaries for the target and the noise which is then subtracted to get the final enhanced image of target with noise reduced to maximum.

The masked image obtained in MATLAB computation as shown in Fig. 9.

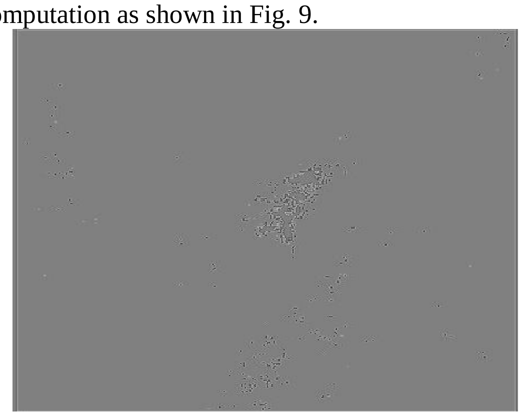

Figure 9: Masked Image Output

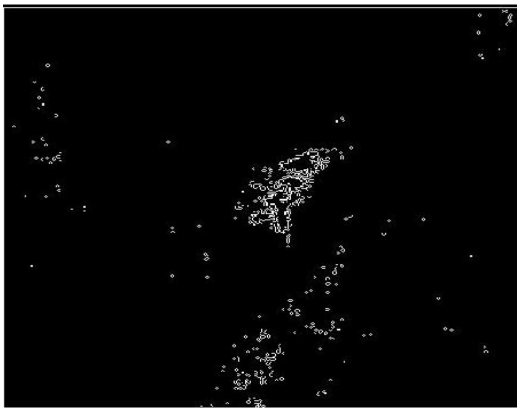

Figure 10 : Laplacian Mask of the Target

In the image the boundaries of the target can be clearly seen. The purpose of defining the boundaries is to eliminate the target from the blurred noise obtained from adaptively filtered image. However in this process some part of noise is also inserted as target boundaries because of its size. After the boundaries have been defined, a filter mask is produced which is used for the subtraction of noise from adaptively filtered image and enhance the target edges.

Fig 11 shows the original image is then subtracted from this filtered image to get the enhanced output image of the target. Area inside the target boundaries as well as some bigger chunks of noise are retained whereas rest of the noise is completely removed making those pixels value to be zero. Thus a final enhanced image is obtained as shown in Fig 12, with clear edges of the target situated at the center of the image. The coordinates of the target can be calculated by measuring the centroid of the image as the target lies at the center itself.

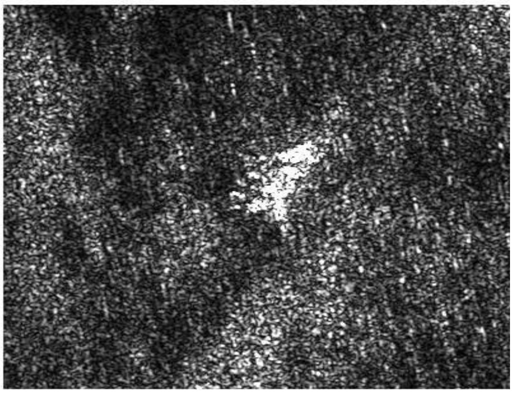

Figure 11: Original Raw Image of The Target

Figure 12 : Result Shows the Enhanced Image with Target in the Center of an Image with Certain Amount of Noise.

IV. CONCLUSION

The difference between the clearness of targets can be clearly seen from the comparison of above two images. In the original image, there is no exact distinction of target boundaries because of the presence of salt and paper noise. In the final image the target can be seen at the center of the image with very less noise. This process consumes very less amount of computing power than the other filtering techniques and produces very sharp, enhanced images also reduces the noise to a significant level. The study of various filters over the SAR image data were carried out to provide the result for the image enhancement. The technique provides the exact methodology and study of image enhancement in presence of salt and pepper noise using the filters algorithm.

V. ACKNOWLEDGEMENT

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