Removal of Speckle Noise From Sar Images Using Various Filters

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***Abstract*:- Synthetic aperture radar (SAR) is widely used in many aspects, such as ecology, hydrology, ocean monitoring, and topographic mapping as it is advantageous of all-day, all-weather, multi-angle view, and penetration of ground objects. When SAR images are created, a type of noise called "speckle noise" naturally appears because of how SAR works. Especially, imaging of high-resolution SAR images is more complex and demanding. However, the existence of speckle noise seriously affects the visual quality of the images. The improper functioning of certain algorithms used to classify SAR images into different categories can happen, which can affect how well they work depending on their intended use. So removal of speckle noise from SAR images is one of the crucial steps in the pre-processing of SAR images. By utilizing various image processing techniques, a customized algorithm of filters and statistical techniques, such as Lee Sigma filter, Boxcar filter and various other filters the speckle noise is removed while preserving the essential features of the image. This evaluate the performance of the algorithm using objective measures such as Peak Signal-to-Noise Ratio(PSNR), Speckle Suppression Index(SSI), Equivalent Number of Looks(ENL), Speckle Suppression and Mean Preservation Index (SMPI) and Mean Square Error(MSE) which demonstrated the effectiveness of the approach in reducing speckle noise while maintaining image quality.**

INTRODUCTION

Synthetic Aperture Radar (SAR) is an active remote sensing technique that uses electromagnetic waves to acquire images of the Earth's surface. SAR works by emitting microwave pulses towards the Earth's surface, which are then reflected back to the sensor. The reflected waves are measured and processed to produce images that represent the characteristics of the Earth's surface.SAR images have a wide range of applications in various fields, including remote sensing, navigation, military surveillance, and disaster management. SAR images are useful in monitoring land use and land cover changes, mapping urban areas, and monitoring agricultural crops. They are also useful for tracking the movement of ice sheets, monitoring ocean waves, and detecting oil spills in the ocean.

SAR images have several advantages over other remote sensing techniques. First, SAR can operate day and night, in all weather conditions, and in the absence of sunlight. This makes it useful for monitoring areas that are difficult to access or are frequently covered by clouds. Second, SAR can penetrate through vegetation and clouds, allowing it to capture information about the Earth's surface that is not visible with optical sensors. Third, SAR can provide high-resolution images with pixel sizes as small as a few centimeters, making it useful for detailed mapping and monitoring. Despite the advantages, SAR images also have some limitations and drawbacks. One major disadvantage of SAR is that the images are affected by speckle noise, which is caused by the interference of the reflected waves. This can reduce the quality of the images and make it difficult to interpret the information. Another disadvantage is that SAR images are affected by topography, which can cause distortions in the images. This can make it difficult to compare images taken at different times and locations. Finally, SAR images require complex processing and interpretation, which can be time-consuming and require specialized knowledge and expertise.

One of the major challenges in working with SAR images is the presence of speckle noise. Speckle noise is caused by the interference of the reflected waves, and it can reduce the quality of the images and make it difficult to interpret the information. Therefore, removing speckle noise is an important step in processing and analyzing SAR images. Several methods have been developed for removing speckle noise from SAR images, including filtering, wavelet transform, and segmentation. Filtering is the most commonly used method for removing speckle noise from SAR images. There are several types of filters that can be used including Boxcar filter, Lee filter, Frost filter, Gamma filter, and Median filter.

BOXCAR FILTER:

The Boxcar filter, also known as the moving average filter, is a simple filter that works by replacing each pixel value with the average of its neighboring pixels within a defined window. The filter is effective in reducing speckle noise in SAR images, but it can also result in over-smoothing and loss of image details. The performance of the filter depends on the size of the window, which should be chosen carefully based on the noise level and the desired level of smoothing.

$$X(i,j) = 1/N \sum Y(i,j)$$

Where

X(i,j) represents the estimated pixel value constructed by computing the sample mean over each pixel neighbourhood.

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Y(i,j) noisy image.

LEE SIGMA FILTER:

The Lee Sigma filter is a well-known filter for removing speckle noise from SAR images. It is based on the assumption that the local statistics of the image are similar to the global statistics. This filter replaces each pixel in an image with a weighted average of the pixels around it. The weights are determined based on the similarity of the pixel values and the variance of the neighborhood.

$$\mathrm{Img(i,j) = Im + W * (Cp - Im)}$$

Where: Img(i,j) is pixel value after filtering

Im is mean of the filter window

Cp is centre pixel

W is a weighting function

FROST FILTER:

The Frost filter is a more sophisticated filter that takes into account the spatial and spectral information of the image. It works by estimating the local statistics of the image and filtering the image based on the estimated statistics. The filter is effective in removing speckle noise while preserving the image details, but it can be computationally expensive.

$$DN = \sum_{nxn} K\alpha e^{-\alpha|t|}$$

Where, $\alpha = \left(\frac{4}{n\bar{\sigma}^2}\right)\left(\frac{\sigma^2}{\bar{I}^2}\right)$

K = Normalized constant

I = Local Mean

σ = Local Variance

$\bar{\sigma}$ = Image coefficient of variable value

n = moving kernel size

$|t| = |X - X_o| + |Y - Y_o|$

GAMMA FILTER:

The Gamma filter is a nonlinear filter that works by enhancing the edges in the image while suppressing the speckle noise. The filter works by estimating the local statistics of the image and adjusting the weights of the neighboring pixels based on the similarity of the pixel values and the variance of the neighborhood. The Gamma filter is effective in preserving the edges and details in the image while removing speckle noise, making it useful for applications such as target detection and classification

G(x,y) = [1 - (V(x,y) / M(x,y))^gamma] * I(x,y)

Where:

- G(x,y) is the filtered output image pixel value at location (x,y)
- V(x,y) is the local variance of the pixel intensity values within a square window centered at (x,y)
- M(x,y) is the local mean of the pixel intensity values within the same window

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- I(x,y) is the input SAR image pixel value at location (x,y)

MEDIAN FILTER:

The Median filter is a simple and fast filter that replaces each pixel with the median of its neighboring pixels. The filter is effective in removing speckle noise while preserving the image details, but it can also produce over-smoothing in areas with high contrast.

$$\hat{f}(x, y) = \text{median}_{(s,t)\epsilon sxy(x,y)}\{g(s,t)\}$$

Where

g(s, t) is a noise corrupted image.

Sxy is set of coordinates in rectangular image window.

Speckle Suppression Index (SSI)

The speckle suppression index (SSI) measures the effectiveness of filters in reducing speckle noise while preserving image quality in SAR images. A higher SSI indicates better filter performance. The SSI is computed based on the ratio of the noise variance in the original image to the noise variance in the filtered image. The SSI is commonly used to compare filter effectiveness and select the most suitable filter for specific applications

$$\text{SSI} = \frac{\sqrt{\text{variance}(I_f)}}{\text{mean}(I_f)} * \frac{\text{mean}(I_f)}{\sqrt{\text{variance}(I_o)}}$$

Equivalent Number of Looks (ENL)

The Equivalent Number of Looks (ENL) measures the signal-to-noise ratio (SNR) in SAR images, with a higher ENL indicating better image quality. It is used to evaluate image quality and determine filter parameters for speckle reduction.

$$\text{ENL (i)} = \frac{(\bar{\hat{x}}(i))^2}{\text{var}(\hat{x}(i)}$$

Speckle Suppression and Mean Preservation Index (SMPI)

The Speckle Suppression and Mean Preservation Index (SMPI) measures the trade-off between speckle reduction and mean preservation in SAR image filters. A higher SMPI indicates better filter performance.

$$\text{SMPI} = Q * \frac{\sqrt{\text{variance}(I_f)}}{\sqrt{\text{variance}(I_o)}}$$

Peak to Signal Noise Ratio (PSNR)

Peak Signal-to-Noise Ratio (PSNR) measures image quality by comparing the maximum pixel value to noise level in decibels. A higher PSNR value indicates better image quality. In SAR image processing, PSNR is used to evaluate speckle reduction filter effectiveness.

$$\text{PSNR} = 10\text{Log}_{10}(\text{MAX}\hat{\ }2/\text{MSE})$$

Where :

MAX is called maximum pixels value.

MSE is called mean square error.

Mean Square Error (MSE)

Mean Square Error (MSE) measures the difference between two images by calculating the average of the squared differences between their pixel values. A lower MSE value indicates a better match.

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$$MSE(i) = \frac{1}{M}\sum_{l=1}^{M}(\hat{x}(l) - x(l))^2$$

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RESULTS

RAW IMAGES

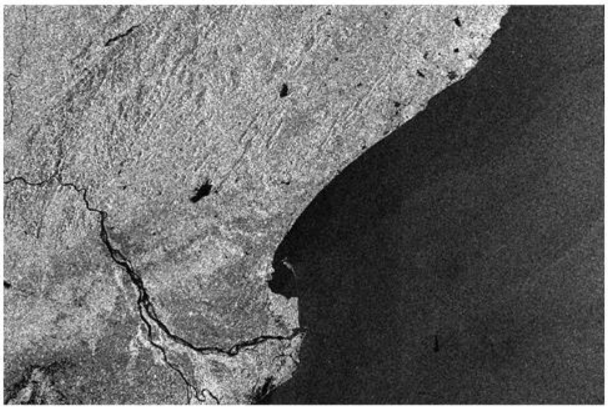

Fig.1a VH Band

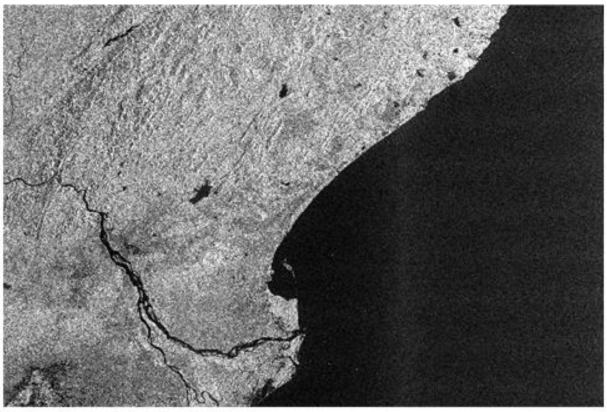

Fig.1b VV Band

BOXCAR FILTER

Fig.2a VH Band

Fig.2b VV Band

LEE SIGMA FILTER

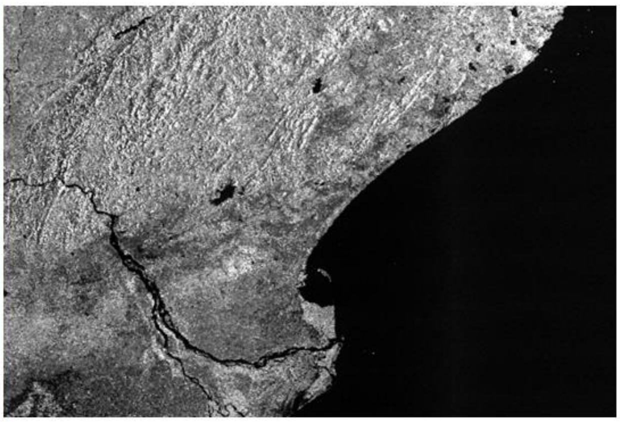

Fig.3a VH Band

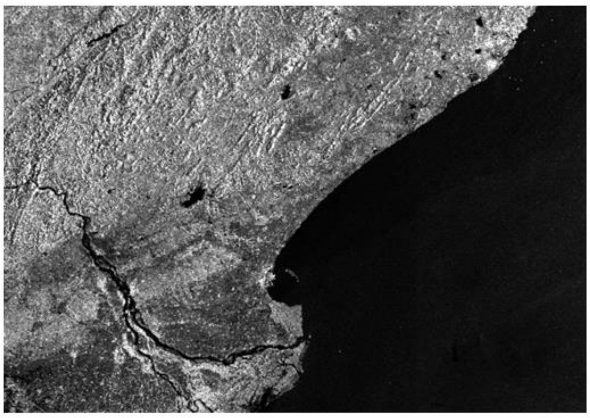

Fig.3b VV Band

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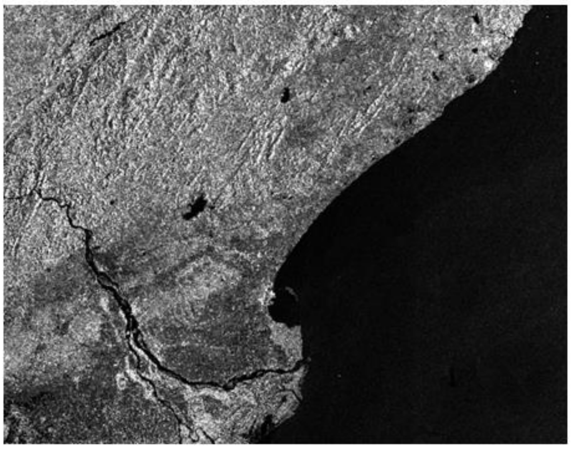
MEDIAN FILTER

Fig.4a VH Band



Fig,4b VV Band

FROST FILTER

Fig.5a VH Band

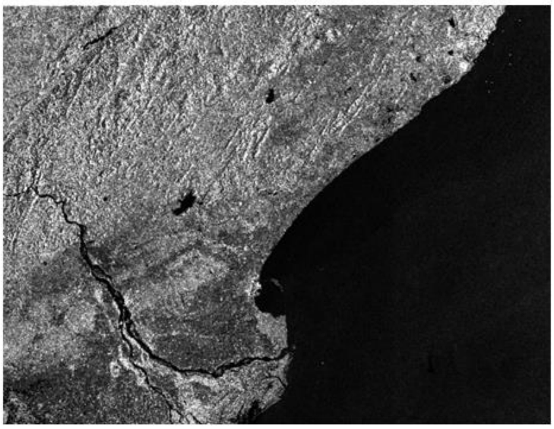


Fig.5b VV Band

GAMMA MAP FILTER

Fig.6a VH Band

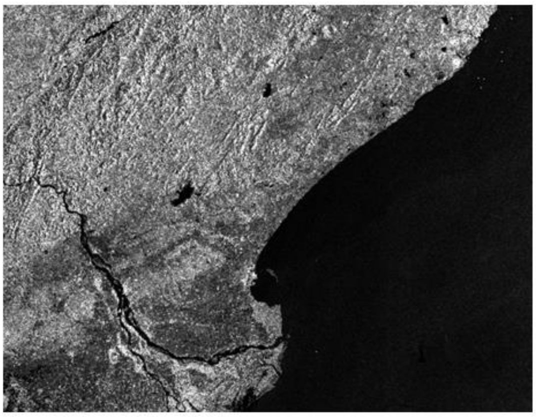


Fig.6b VV Band

SIMULATION RESULTS:

S.NO	FILTERS/PARAMETERS	MSE	SSI	SMPI	ENL	PSNR
1	BOXCAR VH	17.4253	0.967	5.4441	0.5346	35.719
2	MEDIAN VH	6.2269	0.9746	3.5852	0.5236	40.1881
3	FROST VH	16.343	0.9759	5.3406	0.5249	35.9974
4	GAMMA MAP VH	26.368	0.9592	6.5212	0.5435	33.92
5	LEE SIGMA VH	36.9292	0.9491	7.5768	0.5551	32.4571
6	BOXCAR VV	10.2787	0.9355	4.2007	0.5713	38.0114
7	MEDIAN VV	5.3302	0.9448	3.2782	0.5601	40.8634
8	FROST VV	5.8065	0.9394	3.3657	0.5666	40.4916
9	GAMMA MAP VV	9.9053	0.9365	4.1414	0.5701	38.1721
10	LEE SIGMA VV	17.6562	0.9174	5.195	0.594	35.6618

CONCLUSION:

In conclusion, SAR images have numerous applications in various fields, but the presence of speckle noise can reduce their quality and make it difficult to interpret the information. Removing speckle noise from SAR images is an important step in processing and analyzing them. There are several methods for removing speckle noise, but filtering is the most commonly used method. Different types of filters, such as the Lee filter, Frost filter, Gamma filter, and Median filter, can be used depending on the specific requirements of the application. Choosing the appropriate filter is crucial for achieving high-quality SAR images that can be useful for various applications, including environmental monitoring, disaster management, and surveillance.

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