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Noise Reduction from L-Band ALOSPALSAR Data Set Using Spatial Domain Gaussian Low-Pass Filter

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Abstract

The microwave remote sensing system is the broadest tool use to get information about the earth's objects in the form of images. These images are very much affected by various noises, which affects the precision of the images. These, in turn, affect the information present in it. To improve, the quality of satellite images, denoising of the image is an essential task. Gaussian noise majorly seen in all remotely sensed images. Natural sources cause this noise during the acquisition of the image. Many Researchers used Numerous types of filtering techniques to reduce such noises. In this paper, we have focused on lowering Gaussian noise from the microwave satellite dataset. To minimise Gaussian noise, the spatial domain Gaussian Low Pass Filter (GLPF) with different window sizes applied to a single Polarized (HH) L-band ALOS PALSAR satellite SLC level-1 Datasets. The results of filtered images are evaluated based on the respective mean, standard deviation and coefficient of variance.

Keywords: Microwave Image, Gaussian Noise, Gaussian Low Pass filter, window size

1. Introduction

Microwave satellite has the property of high atmospheric transmittances in the microwave frequency range. Microwave satellite provides the earth's object information using electromagnetic radiation in any atmospheric condition. Digital images convey this information to us. Different factors, such as environmental conditions, intensity levels, sensor temperature, etc. affect the imaging sensors' performance during the acquisition of an image. Hence, satellite images are considerably affected by various noise forms, making a random variation in the image's intensities. These variations in intensities affect the quality of the image. So, it is not easy to obtain information about objects quickly. Generally, Speckle noise, Gaussian noise, Salt & Pepper noise, etc. found in microwave satellite images. Hence, denoising a satellite image is a challenging task. Numerous

image enhancement filtering methods are available for noise reduction from these images. [1-3]. this research aims to reduce Gaussian noise from the Single-Polarized (HH) ALOS-PALSAR SLC image. By applying the Spatial domain Gaussian Low Pass Filter (GLPF) technique with a different window size of the filter. Filtered images are examined based on statistical parameters such as standard deviation and coefficient of variance. The experimental work is carried out in Envi 5.3 software. In Microwave remote sensing, the image generated is with the help of echo return signals from objects. This image can be represented and displayed in digital formats by dividing the image areas into small identical-sized and shape boxes known as pixels. Each pixel has a value, which defines each region's brightness in the form of a digital number (DN). The image acquisition process adds different noises at the pixel level.

Two types of noises found in an image are additive and multiplicative noise. Additive noise is a background noise, which gets added to the actual pixel value (DN). Multiplicative noise is available as a speckle in the image. The noise model in microwave images is given by:

$$D_{x,y} = S_{x,y} * U_{x,y} + V_{x,y} \text{-----} \quad (1)$$

In equation (1) $U_{x,y}$ is multiplicative noise. Whereas Gaussian noise is denoted by $V_{x,y}$. The Gaussian noise will change every pixel value by a minor amount from its original value [4][5].

The study conducted shows the immediate attention of researchers in the field of denoising Gaussian noise from the satellite images. The 2nd section presents the literature review for present work. The next section describes the methodology for Spatial domain Gaussian Filtering technique to eliminate noise from an image. 4th description of different statistical parameter to be used in analysis and section 5 and 6 is the implication of the experimental approach for the ALOS-PALSAR datasets, describes the result and discussion of an ideal method used in this work. The last segment summarises the study carried out to arrive at the decisions.

2. Related Work:

In this section, we will discuss the algorithm used by many researchers in recent years for the Gaussian noise reduction. Lucier and et al. [2011] has created the PURE-LET technique to advance a broad class of change thresholding calculations for denoising images contaminated by Gaussian noise [6]. Gnanambal Ilango and R.Marudhachalam [2011] proposed a topological method based on various hybrid filtering techniques to remove Gaussian noise[7]. Here, the filters are a fixed set of approximations and statistical neighbourhood pixel operational processes. Sara Parrolli and others [8] has proposed a novel despeckling algorithm for (SAR) images based on the concepts of nonlocal filtering and wavelet-domain shrinkage to reduce additive Gaussian noise from the SAR images in the year 2012. Tanzila Rehman and others in 2014[9] used the modified fuzzy filter to reduce Gaussian noise and preserve details of

Image simulating with zero mean and 0.01 to 0.05 variance value. Athira K. Vijay1, M. Mathurakani in 2014 [10], had introduced Dual-Tree Complex Wavelet Transform (DT-CWT) along with Byes thresholding. Convolution based on 2D processing to reduce Gaussian noise. Ameen Mohammed Abd Al-salam Selami, Ahmed Freidoon Fadhil in 2016, applied enhancement filters such as the Averaging Enhancement Filter, the GLPF, the Circular Averaging Filter, and The Motion Filter to study the effects of Gaussian Noise on different features of an image [11].

3. Spatial Domain Gaussian Low Pass Filtering:

A Spatial Domain is the aggregate of the pixels combining an image. Filtering is the process of the convolution of a window with an image. Filters enhance or suppress different types of features of an image. The filtering procedure involves:

- 1) Moving a 'window' of a few pixels in different sizes (e.g., 3x3, 5x5, etc.) over every pixel in the image.
- 2) Apply a mathematical calculation using the values of pixels under that window.
- 3) Replace the central pixel with the newly calculated value.
- 4) The window is moved one pixel at a time in both the row and column size.
- 5) Reapplying Step 2nd & 3rd until the whole image is filtered, and a "new" image generation is by varying the calculation performed and the weightings of the individual pixels in the filter window [12][13].

The Gaussian filter is a type of weighted average filter. In this type of filtering technique, the convoy's mask has all positive coefficients with variation in the image's intensities due to Gaussian distribution. Hence, the average weight of each adjacent pixel's is closer to the value of central pixels original value and the maximum Gaussian value replaces the source pixel values. The weights (values) of the central pixel are significantly higher than the weight of its boundary pixel in the image. The Gaussian Low pass filter function for the image given by-

$$g(x,y) = \left(\frac{1}{2\pi\sigma^2}\right) \cdot \exp\left[-\frac{(x^2+y^2)}{2\sigma^2}\right] \text{-----} \quad (2)$$

Where,
g(x, y): is an equation for Gaussian filtered Image

x: distance from the origin in the x-axis
y: distance from the source in the y- axis

σ :standard deviation of the Gaussian distribution
 As σ tends to infinity, $g(x, y)$ becomes an impulse function. It controls the weight of pixels at the centre. It attenuates low-frequency components of an image and leads to the blurring & smoothing effect of the processed image. Hence, Gaussian Filter provides moderate smoothing and preserving edges better than an equally sized Mean filter. after applying the GLPF, a smooth appearance with reduced Gaussian noise found. The magnitude of the Gaussian noise depends on the standard deviation (σ). Noise Magnitude is directly proportional to the standard deviation (σ) [14][15].

4. Statistical Parameters

4.1 Mean (μ):

The Mean, which is the sum of the brightness value observations, divided by the number of amount of pixels values. The Mean is derived using the formula:

$$Mean = \sum_{i=1}^M \sum_{j=1}^N I(i, j) / (MXN) \text{ -----(3)}$$

4.2 Standard Deviation (σ_L):

It is a measure of intensity variation to the intensity dispersion. A low standard deviation shows that the data points tend to be very close to the Mean. The high standard deviation indicates that the intensities spread out over an extensive range. The usage of the following formula gives the Standard Deviation (σ_L) in the image intensity.

$$S. D. = \sqrt{1/(M_L \times N_L) \sum_{i=1}^M \sum_{j=1}^N [I(i, j) - \bar{I}]^2} \text{ ---(4)}$$

Where, M_L and N_L are L th pixel value σ_L to be measure. $I(i, j)$ is the sum of the intensities value of all pixels.

4.3 Coefficient of Variance (CV):

It is the ratio of the standard deviation to mean, also termed as the prevalent quantitative measure for identifying smoothing in the image. The lower value of CV represents a satisfactory level of noise reduction [16].

$$CV = S.D. / Mean \text{ -----(5)}$$

5. Methodology

The L-Band ALOS-PALSAR single-polarized (HH) level-1 SLC images are processed in Envi 5.3 version software. After importing data, the spatial domain Gaussian low-pass filtering (GLPF) technique with different mask size is applied to the input image to reduce additive noise. After filter processing, statistical data of resultant images recorded. The simulated results are compared

based on Standard Deviation and covariance coefficient.

6. Study Area

In this study L-Band ALOS-PALSAR CEOS format datasets are used. PALSAR data are accessible in Level 1.0, Level 1.1 and Level 1.5. Level 1.5 data is the amplitude data generated after range and azimuth compressions and multi-look process, are projected to ground range AND then to a selected map. These are created by applying range and azimuth compressions to the acquired data. It has "11300" number of pixels and "9400" number Of Lines.

6.1 Data Set -I

The Study Area is Akluj, Maharashtra, India, having the centre latitude 17.813° and longitude 75.106° With 34.3° Nadir Angle. The L-band ALOS-PALSAR single-Polarized (HH) SLC format Level-1.5 image acquired on Feb-2017 is used in this paper. As shown in Figure (1).



Fig.1. Data Set-I :Akluj, Maharashtra

6.2 Data Set -II

The study area is Achalpur Camp, Amravati District, Maharashtra, India, with the centre latitude 21.289° and longitude 77.638° with 34.3° Nadir Angle. The L-band ALOS-PALSAR single-polarized (HH) SLC Level-1 Image acquired on 02-Jan-2009 is used in this paper. As shown in Figure (2)[15-17].

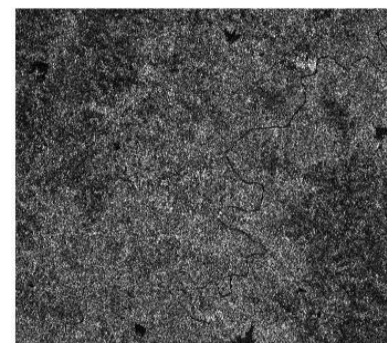


Fig.2. Data Set-II: Achalpur Camp, Amravati, Maharashtra

7. Result and Discussion:

Data Set. I:

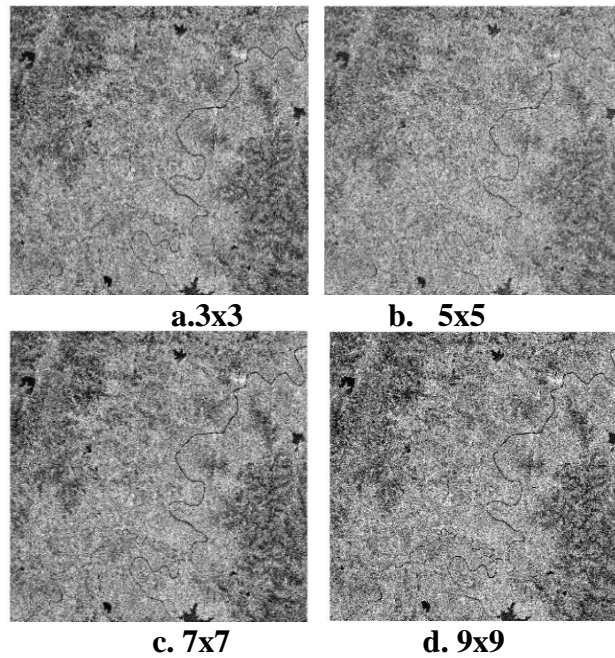


Fig.3. GLPF Filtered Images With Different Window size

Table.1. Statistical parameters of GLPF image with different window size for Band1 for Data

WS	Min	Max	Mean (μ)	S.D. σ_L	CV
3x3	-6.5485	3.5249	-1.702	0.753	0.44225211
5x5	-5.0392	3.3779	-1.631	0.621	0.38093807
7x7	-4.5181	3.2708	-1.607	0.579	0.35994774
9x9	-4.2132	3.1901	-1.596	0.557	0.34916964

Data Set.II:

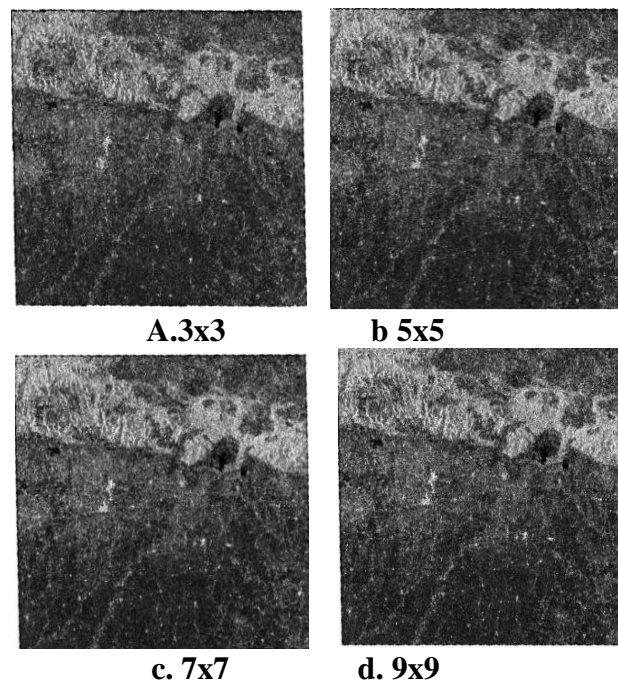


Fig.4. GLPF Filtered Images With Different Window size

Table.2: Statistical parameters of Gaussian Low Pass Filter image with different window sizes for Band Study Area-II.

WS	Min	Max	Mean (μ)	S.D. σ_L	CV
3x3	-3.2768	3.2767	3.5001	2.1212	0.606037
5x5	-3.2768	3.2767	3.5033	1.9917	0.568505
7x7	-3.277	3.277	3.5052	1.9163	0.5468
9x9	-3.2768	3.2767	3.5065	1.8612381	0.530793

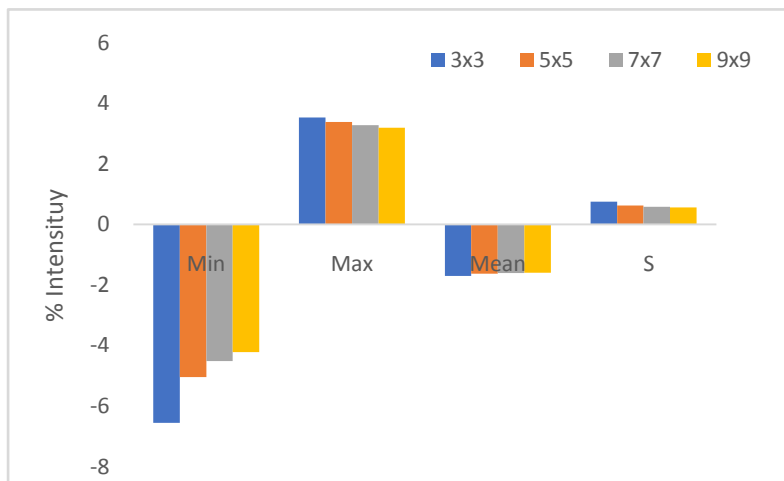


Fig.5. Comparative Study of GLPF with different window sizes for Study Area -I

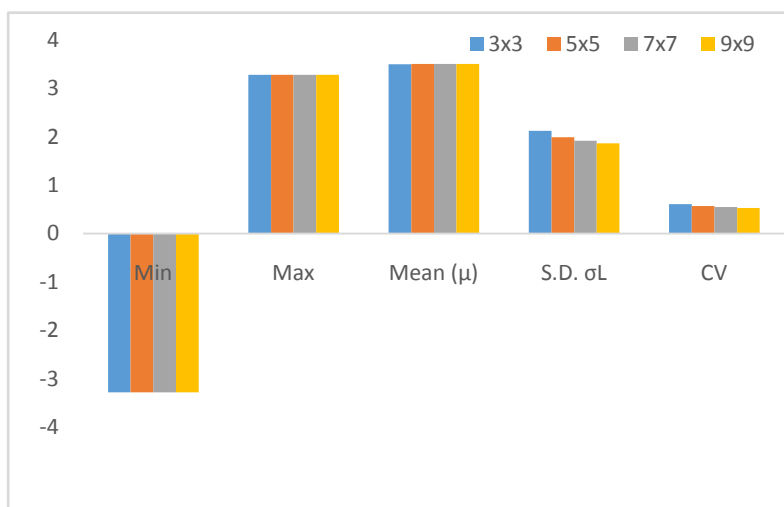


Fig.6. Comparative Study of GLPF with different window sizes for Study Area -II

Fig.3. (a-d) shows the simulated results of GLPF filtered images of different mask sizes viz. 3x3,5x5,7x7and9x9.By observations, it concluded that, as mask size of filter increases, the image gets blurred, and edges in the image get smoothed. Hence the Gaussian noise is reduced without affecting the information contained in the image ; with the change in mask size, the intensity per pixel increases, improving image quality. Table1 compares noise estimated based on variation in

Standard deviation and CV in the Amplitude (Band1) levels for each filtered image. The result indicates that the GLPF image of 9x9 window size has a minimum standard deviation (0.557) and coefficient of variance closer to unity. It implies the Gaussian noise reduction with the reduction in intensity in the filtered image. An increase in window size decreases the Gaussian noise and lowers an image's power by preserving the image's information. Fig.5 is a graphical representation of

variations in GLPF filtered images' and statistical parameters for change in window sizes. It is seen that GLPF with a higher window size has a value closer to the Mean value and has a smaller amount of pixel dispersion than lower window-sized filtered images. According to the result, it observed that the value of Min and Max of higher window size filter images are even lesser than smaller window size filter image, which, in turn, affects the brightness of the image. fig.5. (a-d) shows the simulated results of GLPF filtered images of Study Area-II of different mask sizes viz. 3x3,5x5,7x7 and 9x9.As the mask size increases, images get blurred, and edges in the Image get smoothed. Hence, it reduces the Gaussian noise without affecting the information contained in an image, with the change in the mask size, the intensity per pixel increases, improving image quality. Table.2.represents the calculated evaluation parameters for GLPF denoising filter applied on two different satellite images with varying window sizes. Noise elimination is estimated based to the intensity levels for each filtered image based on variation in Standard Deviation and Coefficient of Variance. The result indicates that the GLPF image of the 9x9 window size has the least Standard deviation (1861.2381) and lower CV (0.530793) for the Band. Thereof specifies the Gaussian noise reduction with the reduction in intensity in the filtered image. An increase in window size decreases the Gaussian noise by preserving the image's information. Figure6 is a graphical representation of variations in GLPF filtered images' statistical parameters for change in window sizes for Study Area-II. It shows that GLPF with a higher window size has a value closer to the Mean value and a smaller amount of pixel dispersion than lower window-sized filter images. According to the result, it observed that the value of Min and Max of higher window size filter image are even lesser than smaller window size.

Conclusion

The simple method of Gaussian Low-pass filtering technique is applied to the L-Band ALOS-PALSAR data two of two different areas.The effect of the GLPF filter with a change in a window size on the image is analysed. From study it is concluded that the GLPF Filter with a larger window size has the least standard deviation and lower Mean than others, substantially reducing

Gaussian noise by lowering the image's intensity level. It also smoothens the edges of the image by protecting the sufficient details of the low contrast. Hence, this type of filtering is useful to get geographical information from all remotely sensed satellite images.

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