Performance Comparison of SAR Image Speckle Noise Removal Algorithms

Yonatan Nagesa
Department of Computer Science
Ambo University
Ethiopia

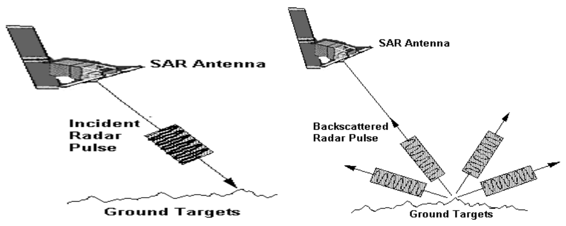
S. Nagarajan
Department of Computer Science
Ambo University
Ethiopia

Fikiru Negesa
Department of Health Informatics
Ambo University
Ethiopia

ABSTRACT
SAR images have achieved a prominent position in the arena of remote sensing and satellite technology. This SAR images can captured in any weather either its day or night, cloudy or sunny. SAR images will find many applications in image processing, it has many application in resource management, agriculture, mineral exploration and environmental monitoring. The useful information of the SAR image also was affected with speckle noise. The noise that corrupt the SAR (Synthetic Aperture Radar) images were affects the appearances of the image is multiplicative or granular speckle noise. Accordingly, for such speckle noise kinds different speckle noise removal method were available. The most significant method that used to remove speckle noise from SAR image is filtering technique. The SAR image speckle noise is sometimes suppressed by removing a speckle noise, using removal filter algorithm on the image before display and further analysis. To do this Median, Guided Filter (GF), Lee, Box, Adaptive or Wiener filter algorithms were used and their performances were compared in PSNR, SNR and MSE and from those all used algorithms the GF achieves better performance in high PSNR value of 37.8342.

Keywords
Filtration Algorithm, SAR, Speckle Noise, Multiplicative Noise.

1. INTRODUCTION
Synthetic aperture radar (SAR) is a kind of consistently imaging radar with both high range and azimuth resolutions. Synthetic aperture radar (SAR) has extensive applications in military and civilian fields due to technology of its facts, such as strong penetrating ability and adaption to severe weathers. It produces high resolution images of earth‘s surface by using special signal processing systems. SAR Automatic Target Recognition Technology (SAR-ATR) wishes at routinely recognizing the targets from SAR images with a cumulative amount of the data acquired by a SAR imaging system [1].To form a SAR image, successive pulses of radio waves are transmitted to illuminate a target scene, and the echo of each pulse is received and recorded. Synthetic-aperture radar (SAR) is a type of radar it is shown in Fig 1(a) and Fig1(b) in which a large, highly-directional rotating antenna used by conventional radar is replaced with many low-directivity small stationary antennas scattered over some area around the target area [2].
It’s known that there are many mutual databases for close range digital photography, such as Image Net, PASCAL, and Label ME, etc. While for SAR, the available large database is very limited and the only publicly released database is MSTAR dataset, which only contained of several separate class of terrain military targets collected by an X-band SAR sensor [3]. In recent years, SAR data is increasing sharply thanks to new satellite missions, various sensors and inter-operability of knowledge archives. Automatic Target Recognition (ATR) of Synthetic Aperture Radar (SAR) images is a neighborhood of continuous research by all branches of military and a few research institutions.



(a) **(b)**

Figure 1 (a) a radar pulse is transmitted from the antenna to the ground and (b) vice versa (Source: https://crisp.nus.edu.sg/research/tutorial)

2. LITERATURE REVIEW
Speckle filtering one among the fore most prominent topics within the SAR image processing research community, who has first tackled this issue using handcrafted feature-based filters. To remove and clear such speckles of image captured by Synthetic Aperture Radar (SAR) is required different algorithms and techniques which is optimized algorithm [4].

The abundant wavelength of radar signals bounds the attainable resolution in cross range direction of real aperture radar systems. Thus, imaging cannot be realized using static radar systems [5]. Noise is the signal that mixes up with the desired signal and corrupts it in any type of communication system. In signal processing adaptive filters are the alternative technique for improving specified speech from the noise. Several algorithms have been proposed in earlier days to detect the desired signal. Least mean square (LMS) algorithm was the most efficient method in terms of computation and storage requirements but it has low convergence speed [6].

Image optimization is the application of an image regularization tool that improves images by providing a sharper shadow. Since SAR is a coherent imager, speckle noise is inherent in the imaging process and can introduce large variability in the imagery that makes interpretation and feature extraction difficult [7]. For this feature extraction and image recognition is important component in image optimization.

Noise in images is the vigorous aspect which degrades the quality of the images. Although many filters are studied in [8] for speckle reduction, and some kernels preferred as they are best matched for SAR images and statistical parameters are calculated for the output images acquired from all the kernels. Samples are the Scan SAR (or TOPS) mode, which assists a wide swath at the cost of an impaired azimuth resolution, and the Spotlight mode, which allows for an enhanced azimuth resolution at the charge of a non-contiguous imaging along the satellite track. To overcome this fundamental limitation, several innovative digital beam forming techniques have been suggested by Alberto Moreira and et al; where the receiving antenna is split into multiple sub-apertures that are connected to individual receiver channels.

Way of SAR images for seep detection is upgraded by a Texture Classifying Neural Network Algorithm (TCNNA), which establishes extents where layers of floating oil overpower Bragg scattering [9]. However, a time series provides sufficient evidence of the release points and general extent even when the seep orientation changes in relation to local winds and currents. An imperative approach for describing the oil slick boundaries is to quantify its texture content, based on the gray speckle of the satellite image. This aspect of the analysis is vital also because the brightness of the images disagrees based on the energy returned to the satellite antenna along the incidence angle. This method serves as a standardization of the aspect of the image [10].

The SAR data-segmentation approach exploited in [11] work includes a smoothing step, aimed at reducing the effect of speckle, and a clustering step, aimed at grouping pixels with statistically similar values. In this the performance comparison of some algorithms accordingly such as Crude segmentation in CERN (Canny Edge Detector and Region Merging) algorithm results is evident, while BIS (Berkeley ImageSeg) algorithm and STM (spanning-tree based) algorithm appear to be more responsive to the features that characterize SAR urban scenes, such as bright scatters, multiple rejections, and positive or negative autocorrelation of pixel disposal.

3. MATERIALS AND METHODS

This research work is about comparing performance of filtering algorithms used for removing speckle noise in SAR image. Figure 2 shows the architecture of proposed work.

3.1 Dataset Collection and preparation

Data CollectionMSTAR database, is dataset collected for the research work, which is provided by the Sandia National Laboratory (SNR) SAR sensor platform operating at X-band. The gathering was cooperatively sponsored by Defense Advanced Research Projects Agency (DARPA) and Air force lab as a part of the Moving and Stationary Target Acquisition and Recognition (MSTAR) program. Obvious that there are many mutual databases for close range photography, like Image Net, PASCAL, and Label ME, etc. While for SAR, the available large database is extremely limited and therefore the only public released database is MSTAR [12], which only contained of several separate class of terrain military targets collected by an X-band SAR sensor.

Table 1.Image number observed in each class labels

S/N	Label/Class	Count
1	**BTR60**	**256**
2	**D7**	**299**
3	**SLICY**	**297**
4	**T62**	**299**
5	**ZIL131**	**299**
6	**ZSU234**	**296**

The collected datasets is containing multiple sorts of ground military target, including BTR-60; tank: T-62 SLICY; defense unit; ZSU-234; truck: ZIL-131; bulldozer: D7. The dataset contains 1746 of total target of SAR image data and therefore the number of image observed in each class label of images are computed as shown in table 1 .

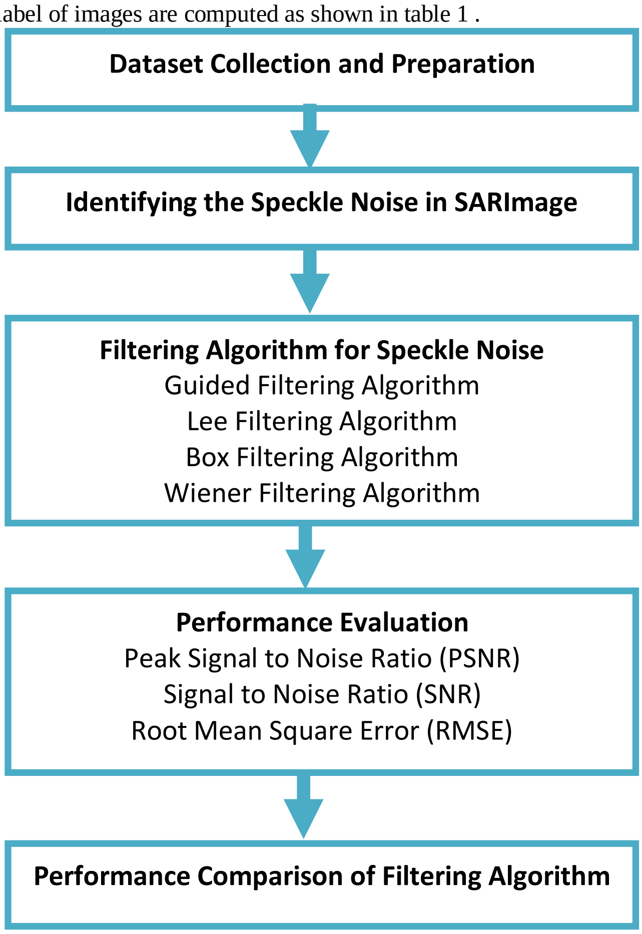
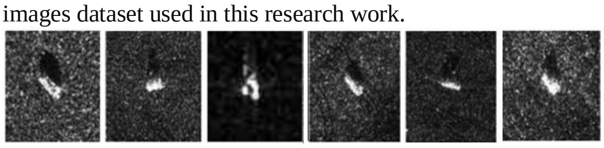


Figure 2: Architecture of Proposed Research work

Below figure 2 shows corresponding sample MSTAR SAR images dataset used in this research work.



(a) (b) (c) (d) (e) (f)

Figure 2. (a)BTR60(b)D7 (c)SLICY (d)T62(e)ZIL131 (f)ZSU234

3.2 Identifying the Speckle noise in SAR

In this thesis work, the synthetic aperture radar image that has pains of speckle noises was taken. In this, the histogram is used to calculate a number of colors present in gray scale image which is between 0 – 255 and it's also count of number of times each pixel appeared in an image. The following is shows that the SAR images were affected with speckle noise as from below figure 3 result. From the following histograms results show that the image has high black color value of 1500 from 0-50 and it comes to show the white color value from 50-150 and almost all very low white color value is shown from 200-250.

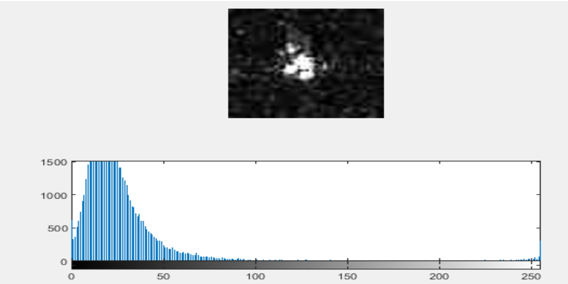


Figure 3 SAR Image Histogram with Speckle Noise.

3.3 Filtering Algorithm for Speckle Noise

Preprocessing data may be a procedure that involves modifying data into a clear format. Actually world data is often imperfect, unpredictable or lacking in certain behaviors or trends, and is probably going to contain many errors. Data preprocessing may be a confirmed method of resolving such issues. Data preprocessing also prepares data for further processing. For the research work the SAR image data is that the data that's infected with speckle noise and it needs speckle noise removal algorithms. For this, the Wiener, Lee, Box, Median and Guided Filtration algorithms are wont to filter the speckle noise from the SAR image data for preprocessing.

3.4 Metrics for performance Evaluation

All image-acquirement processes are subject to noise of some type, so there's little point in ignoring it; the perfect situation of no noise never occurs in practice. Noise can't be expected accurately since its arbitrary nature, and can't even be measured accurately from a loud image, since the contribution to the grey levels of the noise can’t be distinguished from the pixel data. Satellite images are usually degraded by noise during image acquisition and transmission process [13]. The most purpose of the noise reduction technique is to get rid of speckle noise by retaining the important feature of the pictures. Mathematically there are two basic models of noise: Additive noise and Multiplicative noise. Additive noise is systematic in nature and may be easily modeled and hence removed or reduced easily; whereas multiplicative noise is image dependent, complex to model and hence difficult to scale back. Several approaches are there for noise reduction. Generally speckle noise is usually found in synthetic aperture radar images, satellite images and medical images [14]. Estimation of Signal to Noise Ratio (SNR) compares the extent of desired signal to the extent of ground noise. The greater the SNR ratio, the lesser conspicuous the ground noise is. SNR [15] in decibels is defined as:

$$SNR = 10\log(\sigma^2 g / \sigma^2 e)$$

Where, σ^2_g, is the change of the noise free image and σ^2_e is that the change of the noise free image and σ2e is that the change of error (between the first and denoised image). Sunnier areas have a stronger signal due to more light, resulting in greater overall SNR. Sunnier areas have a stronger signal thanks to more light, leading to greater overall SNR.

Estimation of RMSE

Mean square error (MSE) is given by:

$$MSE = \sum_{i=j=1}^{N} [f(i,j) - F(i,j)^2] / N^2$$

Where, f is the original image F is the image denoised with some filter and N is the size of image [17].

$$RMSE = \sqrt{MSE}$$

Estimation of PSNR:

PSNR gives the ratio between possible power of a signal and the power of corrupting noise present in the image [16].

$$PSNR = 20log10\left(\frac{255}{RMSE}\right)$$

Greater the PSNR gives lower the noise in the image i.e. greater image quality [16].

4. RESULTS AND DISCUSSION

To remove the SAR image speckle noise, the SAR image speckle noise filtration algorithms such Lee, Box, Wiener, Guided and Median filtration algorithms and results of those algorithms discussed below

4.1 Wiener (Adaptive) Filter algorithm

A Wiener filter is exclusively proper for speckle and noise discount in multilook synthetic aperture radar (SAR) imagery [18]. It was anticipated by Norbert Wiener during the 1940s and published in 1949. It is also recognized as Least Mean Square Filter. It has ability to restore images even if they are degraded or blurred. Wiener filters workings on the origin of computation of local image variance. Hence when local alteration of the image is large the smoothing is done in smaller amount and if local variance is small it performs more smoothing.Wiener filter also requires more computation time [19]. This approach of Wiener filter results better than linear filtering [20]. It has following mathematical formula:

$$f(u,v) = \left[\frac{H(u,v)^*}{H(u,v)^2 \frac{[sn(u,v)]}{sf(u,v)}}\right] G(u,v)$$

where$H(u,v) =$ Degrade function and $H(u,v)^* =$ Conjugate complex, $G(u,v) =$Degraded image, $sn(u,v) =$ Power spectra of noise and $sf(u,v) =$ Power spectra of original image.

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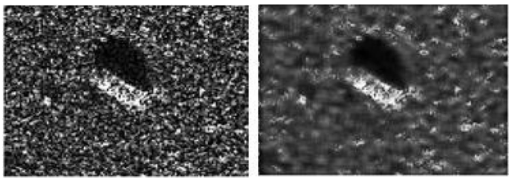


(a) Original SAR image (b) Filtered SAR image

Figure 4. Wiener filter algorithm (a) Original and (b) Filtered SAR image.

From above result of figure 3 of wiener filter algorithm the original SAR image (a) is filtered and the algorithm result after speckle noise removed is viewed as filtered SAR image (b). And the PSNR, SNR and MSE value of the algorithm to remove speckle noise is calculated and it achieves PSNR value of **14.7660,** PSN value of **6.0111** and MSE value of **2170.1087.**

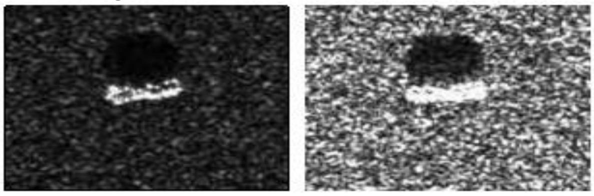
4.2 Lee Filter

Lee filters to smooth speckled data that possess intensity related to the image and that also have an additive or multiplicative component. It conserves image sharpness and detail while overwhelming noise. The pixel being filtered is substituted by a value considered using the nearby pixels. Every pixel is set into one of three classes, which are treated as follows:

- Homogeneous: The pixel value is substituted by the ordinary of the filter window.

- Heterogeneous: The pixel value is substituted by a weighted average.
- Point target: The pixel value is not altered.

The matlab code used to perform Lee filter is K **= Lee_filter (I, J, [5 5]).** In this I (Original image) and J (Altered image) with filtering size of 5x5.



(a) Original SAR image (b) Filtered SAR image

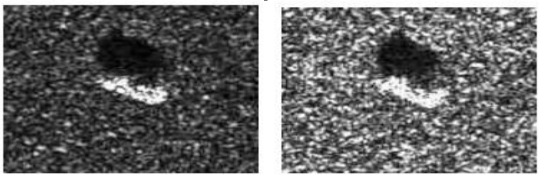
Figure 5. Lee filter algorithm (a) Original and (b) Filtered SAR image

From above result of figure 4 of Lee filter algorithm the original SAR image (a) is filtered and the algorithm result after speckle noise removed is viewed as filtered SAR image (b). And the PSNR, SNR and MSE value of the algorithm to remove speckle noise is calculated and it achieves PSNR value of **23.5234,** PSN value of **4.8555** and MSE value of **288.8965.**

The performance comparison with each other algorithm is measured in high PSNR value of each other's. The algorithm with high PSNR value is best for speckle removal performance [16].

4.3 Box Filter Algorithm

A box filter is also known as spatial domain linear filter in which every pixel in the successive image has a value equal to the ordinary value of its nearby pixels in the input image. It is a form of low-pass "blurring") filter. A box filter is so-called a mean filter. The matlab code used to perform box filter is **B = imboxfilt (A,filterSize).** It filters image A with a 2-D, 3-by-3 box filter with size indicated by filter Size.



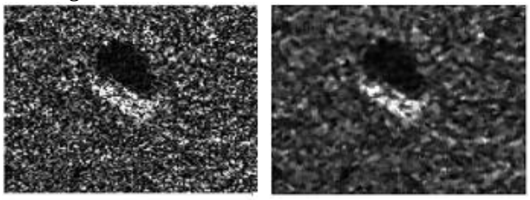
(a) Original SAR image (b) Filtered SAR image

Figure 6. Box filter algorithm (a) Original and (b) Filtered SAR image

From results of figure 5 of Box filter algorithm the first SAR image (a) is filtered and therefore the algorithm result after speckle noise removed is viewed as filtered SAR image (b). And therefore the PSNR, SNR and MSE value of the algorithm to get rid of speckle noise is calculated and it achieves PSNR value of 23.5139, PSN value of 4.8460 and MSE value of 289.5294. The performance comparison with other algorithm is measured in high PSNR value with each other's.

4.4 Median Filter Algorithm

Median filter may be a non-linear filtering technique for speckle noise reduction [21]. It gives pretty better result than the mean filter. Here midpoint pixel is replaced by the median of all pixels and hence produces less blurring. Thanks to this nature it's wont to reduce speckle noise. Advantage is it preserves the sides [19]. Median filter follows algorithm as follows: - Take a 3 × 3 (or 5×5 etc.) region centered on the pixel (i, j). - Type the intensity values of the pixels within the region into ascending order. - Choice the mid value because the new value of pixel (i, j). During this also I (Original image) and J (Altered image) with filtering size of 5x5.



(a) Original SAR image (b) Filtered SAR image

Figure 7. Median filter algorithm (a) Original and (b) filtered SAR image

From results of figure 6 of Median filter algorithm the first SAR image (a) is filtered and therefore the algorithm result after speckle noise removed is viewed as filtered SAR image (b). And therefore the PSNR, SNR and MSE value of the algorithm to get rid of speckle noise is calculated and it achieves PSNR value of 13.2904, PSN value of 4.5287 and MSE value of 3021.9628. The performance comparison with other algorithm is measured in high PSNR value of with each other's.

4.5 Guided Filter Algorithm

Coherent noise often interferes with synthetic aperture radar (SAR), which features a huge impact on subsequent processing and analysis. The guided filter computes the filtering output by considering the content of a guidance image, which may be the input image itself or another different image. Moreover, the guided filter naturally features a fast and non-approximate linear time algorithm, no matter the kernel size and therefore the intensity range [22]. The method of removing the noise using the GF is as follows. GF models the output image *qi* for the guidance image *Ik* of the window ωk region with the middle pixel *k* in the image, as follows:

$$qi = akIk + bk, \forall i = \omega k$$

Where ak and bk are linear coefficients estimated form the window ωk. Equation (4-5) removes unwanted texture or noise to work out the linear coefficients.

$$qi = pi - ni$$

Here, $pi$and ni denote the input image and noise component, respectively. The linear coefficients are obtained by Equation(2-6) to attenuate the difference between the input image pi and the output image.

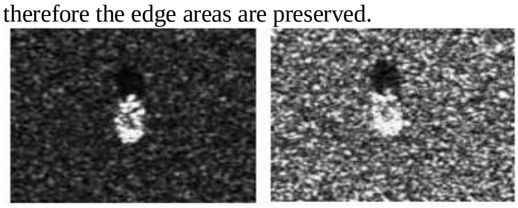
$$E(ak, bk) = \sum_{i\epsilon\omega k} (akIk + bk - pi)^2 + \in a_k^2$$

Where ε may be a normalization parameter that serves to stop ak from becoming infinitely large. The minimization method of the liner coefficient in Equation (2-6) is as follows:

$$ak = \frac{\frac{1}{|\omega|}\sum_{i\epsilon\omega k} Iipi - \mu k\bar{p}k}{\sigma_k^2 + \varepsilon}$$

$$bk = \bar{p}k - ak\mu k$$

Here, $\mu k$and σ_k^2 are the mean and variance of the guidance image within the window ωk. |ω| represents the amount of pixels within the maskωk, and $\bar{p}k=\frac{1}{|\omega|}\bar{p}i$. Because the window size ωk and ε adjust, the noise is removed and therefore the edge areas are preserved.



(a) Original SAR image (b) Filtered SAR image

Figure 8. Guided Filter algorithm (a) Original and (b) filtered SAR image

From above results of figure 7 of Guided filter algorithm the first SAR image (a) is filtered and therefore the algorithm result after speckle noise removed is viewed as filtered SAR image (b). And therefore the PSNR, SNR and MSE value ofthe algorithm to get rid of speckle noise is calculated and it achieves PSNR value of 37.8342, PSN value of 29.0716 and MSE value of 10.7068. The performance comparison with other algorithm is measured in high PSNR value of with each other's. So this algorithm achieves high PSNR value in SAR image speckle noise removal technique.

4.6 Performance Comparison of Filtering algorithms

The researcher also discussed research problems those were speckle noise that affects the appearances of the SAR images. To beat the challenges and problems identified in speckle noise, filtration algorithms to get rid of speckle noise from the pictures were used. With discussing specified challenges and problems, the researcher were proposed different SAR image filtration algorithm to get rid of SAR image speckle noise. The used speckle noise removal filtration algorithms also were compared in their performance. From those used filtration algorithms, Guided Filtration algorithm achieves better performance to get rid of the speckle in high PSNR value of **37.8342**.

Table 2: Comparative study of SAR image Speckle noise filtration algorithm

S/N	Filters	PSNR	SNR	MSE
1	**Wiener Filter**	**14.7660**	**6.0111**	**2170.1087**
2	**Lee Filter**	**23.5234**	**4.8555**	**288.8965**
3	**Box Filter**	**23.5139**	**4.8460**	**289.5294**
4	**Median Filter**	**13.2904**	**4.5287**	**3021.9628**
5	**Guided Filter**	**37.8342**	**29.0716**	**10.7068**

It is concluded from Table 2 above SAR image speckle noise removal filtration algorithms performance comparison, the Guided filter algorithm achieves best result with the PSNR value of **37.8342**. The higher the PSNR value gives lower the noise in the image i.e. higher image quality [16]. Accordingly, The GF algorithm achieves best SAR image speckle noise removal result from them. The next one is Lee filter algorithm with PSNR value of **23.5234**, Box filter with PSNR value of **23.5139**, Wiener filter with PSNR value of **14.7660** and median filter with PSNR value of **13.2904** respectively.

5. CONCLUSION

It is obvious that the SAR image is septic with Multiplicative or granular speckle noise. For the SAR image multiplicative speckle noise removals, different filtration algorithms are used. Why because filter method is the most interested technique used to remove SAR image speckle noise. For this, five filter algorithms were used and their performance to remove the speckle noise on SAR image also compared in high PSNR value. From those used five filtration algorithms, the Guided Filtration algorithm achieves better performance in high PSNR value of **37.8342**. The researchers can also concentrate on some other filtering algorithm for removing SAR image speckle noise that will support for their performance comparison.

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