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Comparison of Various Speckle Noise Reduction Filters on Synthetic Aperture Radar Image

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Abstract
Synthetic Aperture Radar (SAR) image with its advantages, is becoming popular than the optical image in earth observation using the remote-sensing techniques. The SAR image has a high resolution and not influenced by weather conditions either day or night. SAR's image formation process led to speckle noise; it causes difficulties during the process of interpretation and analysis of SAR images. Thus, speckle noise reduction needs to be deployed prior to the use of the SAR images. The ideal speckle filter has the capability of reducing speckle noise without losing the information and content, while preserving the edges and features. To date, various noise filters have been designed for different purposes and different capacities. In this study, we discussed four filters, namely Lee, Frost, Median and Mean filter. Those four filters are analyzed and compared based upon the quality parameter and statistical performance using SAR sample image respectively. We are analyzing quality parameter and comparing statistical performance of Lee, Frost, Mean and Median filters for SAR sample image. The results show Mean Square Error (MSE), Average Difference (AD), Peak Signal to Noise Ratio (PSNR), Signal to Noise Ratio (SNR) and Structural Similarity Index Measure (SSIM) value that generated on SAR image with four different areas by Frost filter performs better than the other filter. Visual interpretation of the de-speckle image that filtered with Frost filter shows sharpens edge and preserved texture to the SAR image.

Keywords: synthetic aperture radar (SAR), speckle noise, de-speckle, image filter, image processing

INTRODUCTION

Synthetic Aperture Radar (SAR) is a type of sensor used for observation and characterization of Earth's surface [1]. SAR sensor has several advantages such as the ability to produce high spatial resolution images, capable to observe in the day and night and all-weather condition [2]. SAR is categorized as an active sensor, it sends electromagnetic waves into the target in earth surface and processes the signals that reflected from the target by coherently [3].

Nevertheless, the SAR image suffers from additive and multiplicative noise. The additive noise comes from the receiver thermal noise. However, the image is mostly affected by multiplicative noise compared to additive noise. This multiplicative noise is also known as speckle noise and causes difficulties on interpretation, analyzing, detection and classification process of the SAR image [2,3,4]. Consequently, required a pre-processing step in SAR image before the advanced uses. The speckle noise reduction is an important step to do that. The aim of a speckle noise reduction is to remove noise by smoothing the regions of image while keep preserve on texture information and edges. Various researchers have conducted the speckle noise reduction with several proposed methods with their own strength and limitation [5].

In this study, we apply various filters, namely Frost filter [6,7,8], Lee filter [6], [9,10], Median filter [6], [11,12] and Mean filter [6], [11,12], into the SAR image. These adaptive filters are the most commonly used in SAR imagery pre-processing. There are many types of SAR images [13] that related to this study [1], [3] used Polarimetric SAR (PolSAR) image in their work, [5] used AirSAR image in their work, and in this study we apply that filter into ALOS-PALSAR image. The filters perform on 3x3 size of the moving kernel window and applied into several earth surface type surfaces. The evaluation of filter performance includes several criteria such as, preservation of the mean, reduction of the standard deviation, preservation of the edges and texture preservation. The main objective of the work presented in this study is to select most suitable and the best filter for pre-processing of ALOS-PALSAR's original image that will use in the future work.

SPECKLE NOISE

Speckle noise is generated during the process of creating the SAR image, that cause by coherent radiation. This noise is an undesired effect that degrades the quality of images, and mostly categorized as multiplicative noise [14]. SAR images also have statistical property that mostly evolved from multiplicative noise model. This image can be formed as multiplicative noise models as follows [10]:

$$I(t) = R(t).v(t) \quad (1)$$

where *I (t)* is the noise-affected signal, *R(t)* is original image or the radar backscatter property without noise of ground targets and *v(t)* is speckle noise and it is independent with *R(t)*. SAR speckle that generated by a zero-mean random phase of echo signals, causes the mean value of v(t) is one, and its variance is relevant with the equivalent number of SAR images [10].

The existence of speckle noise in SAR image will distract detection and classification process [4]. Thus, speckle noise must be eliminated during the pre-processing of SAR images.