SWT-based Wavelet Filter Application for De-noising of Remotely Sensed Imageries

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Abstract: Wavelet scheme can be applied to the various remote sensing problems: conventional multi-resolution image analysis, compression of large image sets, fusion of heterogeneous sensor image and segmentation of features. In this study, we attempted wavelet-based filtering and its analysis. Traditionally, statistical methods and adaptive filter are used to manipulate noises in the image processing procedure. While we tried to filter random noise from optical image and radar image using Discrete Wavelet Transform (DWT) and Stationary Wavelet Transform (SWT) and compared with existing methods such as median filter and adaptive filter. In result, SWT preserved boundaries and reduced noises most effectively. If appropriate thresholds are used, wavelet filtering will be applied to detect road boundaries, buildings, cars and other complex features from high-resolution imagery in an urban environment as well as noise filtering

Keywords: wavelet-based filtering, Discrete Wavelet Transform, Stationary Wavelet Transform

1. Introduction

Several satellites with radar and high-resolution imaging systems were launched and the use of remote sensing data is expected to be increased. Noise reduction has been a primary concern to image processing especially synthetic aperture radar (SAR) imagery.

In this paper, we proposed an approach based on wavelet theory to provide an enhanced approach for eliminating such noise source. It is well known that wavelet transform is a signal processing technique which can display the signals on in both time and frequency domain. Wavelet transform is superior approach to other time-frequency analysis tools because its time scale width of the window can be stretched to match the original signal, especially in image processing studies. This makes it particularly useful for non-stationary signal analysis, such as noises and transients. For a discrete signal, a fast algorithm of discrete wavelet transform (DWT) is multi-resolution analysis, which is a non-redundant decomposition. The drawback of non-redundant transform is their non-invariance in time/space, i.e., the coefficients of a delayed signal are not a time-shifted version those of the original signal. The stationary wavelet transform (SWT) was introduced in 1996 to make the wavelet decomposition time invariant (J.C. Pesquet et al, 1996). This improves the power of wavelet in signal de-noising. In this paper, we applied the DWT and SWT methods to preprocess the optical and SAR images for removing the random noises. We also compare this method with other two traditional denoising methods, namely median filter and enhance Lee filter.

2. Methodology

The discrete wavelet transform (DWT) is known to one of the most useful techniques for multi - resolution image analysis. Furthermore, the wavelet scheme composed of the wavelet transformation and its inverse transformation provides a powerful and flexible set of tools for handling problems in noise removal, signal or image compression, object detection, image enhancement and so on (Mallat, 1989). In the traditional DWT transform, a downsampling algorithm is used to perform the transformation. Therefore, the whole length of the function will reduce by half after the transformation. This process continues until the length of the function becomes one. However, for stationary wavelet transform (SWT), instead of downsampling, an upsampling procedure is carried out before performing filter convolution at each scale. This property is useful for several applications such as breakdown points detection and denosing.

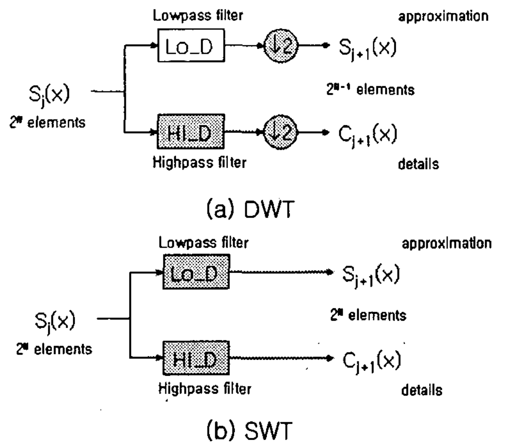
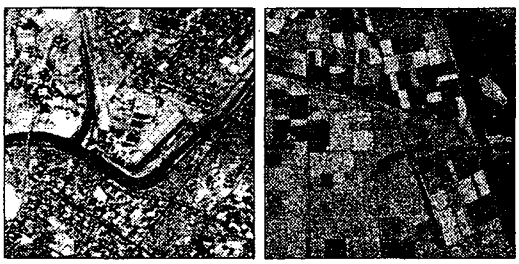


Fig. 1 The comparison of DWT and SWT procedure

3. Results and Discussion



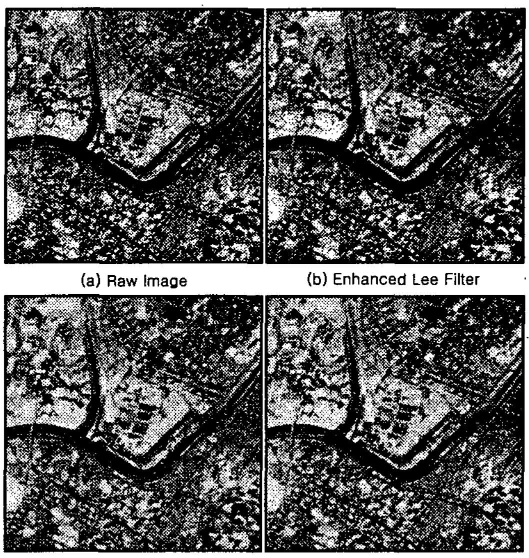
(a) KOMPSAT EOC PAN Image (b) AirSAR C band HH

Fig. 2 The test dataset.

KOMPSAT-EOC image and AirSAR image were used at the experiments in this study: KOMPSAT-EOC panchromatic imagery (Fig. 2(a)) and AirSAR C band image (Fig. 2(b)). These images are covered with regions around Namyangju-city bordered with Seoul, Geounggi-do and Flevoland, Netherlands respectively. SAR image is the sub-scene of test data set for GRSS-DFC members.

The first example is the reduction of arbitrary noise using KOMPSAT image. At first, we added random speckle noise to KOMPSAT image. And then DWT and SWT filter were applied to the noisy image. In order to compare the performance of the DWT and SWT with other methods, the widely used adaptive filter and median filter are also applied. The filtered results were compared with raw image, which is non-noise image. Extensive tests are also performed using various wavelets for the same image. In this study, we used haar, daubuchies (db) 4, 8, coiflets (coif) 1 and symlets (sym) 2. The second example is a SAR speckle noise reduction. We applied same filters to SAR image without adding speckle noise, because SAR image contains speckle noise.

Their effects were evaluated from the aspects of noise reduction and edge preservation. SWT is the most effective method for filtering visually in both KOMPSAT and SAR image. In order to provide a quantitative measure of the resultant images, we evaluated them using an universal image quality index. The universal index proposed in (Zhou Wang, 2002) is presented here.



(a) Raw Image (b) Enhanced Lee Filter

(c) DWT db8 (d) SWT db8

Fig. 3 Raw image and filtered images of KOMPSAT EOC image. Raw image is added random speckle noise to Fig. 2(a).

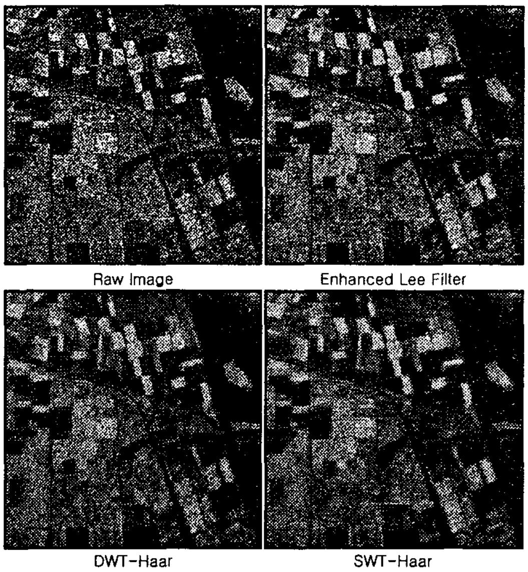


Fig. 3 Raw image and filtered images of AirSAR C band image.

Let $x=\{x_i|i=1, 2, \ldots, N\}$ and $y=\{y_i|i=1, 2, \ldots, N\}$ be the original and the test image signals, respectively. A universal image quality index is defined as

$$Q=\frac{4\sigma_{xy}\bar{x}\bar{y}}{(\sigma_x^2+\sigma_y^2)[(\bar{x})^2+(\bar{y})^2]} \quad (1)$$

Where

$$\bar{x}=\frac{1}{N}\sum_{i=1}^{N}x_i, \quad \bar{y}=\frac{1}{N}\sum_{i=1}^{N}y_i$$

$$\sigma_x^2=\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})^2, \quad \sigma_y^2=\frac{1}{N-1}\sum_{i=1}^{N}(y_i-\bar{y})^2$$

$$\sigma_{xy}=\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})(y_i-\bar{y}).$$

The dynamic range of Q is [-1, 1]. The best value 1 is achieved if $y_i=x_i$ and only if for all i=1, 2, …, N. The lowest value of -1 occurs when $y_i=2\bar{x}-x_i$ for all i=1, 2, …, N. This quality index models any distortion as a combination of three different factors: loss of correlation, luminance distortion, and contrast distortion.

The denoised image quality via several example wavelets and traditional filtering performance are shown in Table 1. Using this index, the quality of the denoised images of KOMPSAT-EOC by median, Enhanced Lee filter, DWT (db 8) and SWT (db 8) are 0.9219, 0.9312, 0.9318 and 0.9321, respectively.

In case of SAR, the quality of the denoised images by median, Enhanced Lee filter, DWT (haar) and SWT (haar) are 0.7672, 0.7983, 0.9009 and 0.9213 respectively.

It is clear that the SWT denoising achieves a better image quality than DWT for every wavelet if the decomposition level and thresholding rules keep the same. The index of median and enhanced Lee filter is far poorer than that of the SWT.

	KOMPSAT	SAR
Median	0.9219	0.7672
Enhanced Lee	0.9312	0.7983
DWT haar	0.9219	0.9009
DWT db4	0.9316	0.9017
DWT db8	0.9318	0.9112
DWT coif1	0.9312	0.9115
DWT sym2	0.9312	0.9114
SWT haar	0.9307	0.9213
SWT db4	0.9319	0.9203
SWT db8	0.9321	0.9137
SWT coif1	0.9316	0.9203
SWT sym2	0.9316	0.9205

Table 1 Comparative performance of the quality index using median, enhanced lee filter, DWT and SWT.

4. Conclusion

In this paper, a wavelet approach to deal with denoising image analysis is presented.

The new approach adopts the denoising by SWT. This image processing method has an obvious advantage, namely time invariance. This makes it particularly useful in recognizing the noises in SAR image. The simulation results applied on image examples verified this enhanced characteristic and denoising quality of the image analysis. The SWT provides a better performance in denoising image than traditional filtering method and discrete wavelet transform. We can use various wavelets and threshold during filtering procedure and get different filtered results. If appropriate thresholds are used, wavelet filtering will be applied to detect road boundaries, buildings, cars and other complex features from high-resolution imagery in an urban environment as well as noise filtering.

References

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