SPECKLE REDUCTION OF SAR IMAGES USING RATIONAL DILATION WAVELET TRANSFORMATION

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ABSTRACT

In this paper we are proposing new wavelet based algorithm for speckle reduction of synthetic aperture radar images, which uses combination of rational-dilation wavelet transformation which is a more flexible family of wavelet transforms for which the frequency resolution can be varied and Generalized Narrowband Lowpass Digital Differentiator. Furthermore instead of using existing thresholding techniques such as sure shrinkage, Bayesian shrinkage, universal thresholding, normal thresholding, visu thresholding, soft and hard thresholding, we use brute force thresholding, which iteratively run the whole algorithm for each possible candidate value of threshold and saves each result in array and finally selects the value for threshold that gives best possible results. That is why it is slow as compared to existing thresholding techniques but gives best results under the given algorithm for speckle reduction.

Keywords: SAR,MAP,MSE

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1.INTRODUCTION

SAR Image Statistics:

SAR images are subject to a phenomenon called speckle that affects all coherent imaging systems and, therefore, can be observed in laser, acoustic and radar images. Basically, this usually disturbing effect is caused by random interferences, either constructive or destructive, between the electromagnetic waves which are reflected from different scatterers present in the imaged area. Comparing SAR images to optical data, a clear difference becomes visible: In contrast to incoherently imaged scenes, SAR images appear to be affected by a granular and rather strong noise named speckle. This effect is well-known since many years and has been studied intensively in laser imaging. Speckle becomes visible only in the detected amplitude or intensity signal. The complex signal by itself is distorted by thermal noise and signal processing induced effects only. As a consequence of the speckle phenomenon, the interpretation of detected SAR images is highly disturbed and cannot be done with standard tools developed for non-coherent imagery.

SAR is a time-ranging system, which allows to generate images from backscattered intensity of electromagnetic waves. To obtain an adequate resolution, techniques like pulse compression and synthetic aperture are used.

Radiometrical and geometrical information in SAR images are influenced by the topography of the imaged scene. For that reason, SAR data usually require geometrical correction and radiometrical calibration in combination with terrain correction to be of use in cartography, for example.

A phenomenon called speckle highly degrades the radiometric resolution of SAR images and hinders their interpretation. Speckle is considered as a multiplicative granular noise only visible in detected SAR data.

In general, speckle noise shows some degree of correlation, which is due to the SAR system's point-spread-function. However, this correlation is not considered in commonly used image processing techniques since it is difficult to be taken into account. Consequently, these effects are often reduced by appropriate techniques, like subsampling.

The statistics of speckle noise have been described because they are necessary to deal with this effect within a Bayesian framework. In the following, methods will be discussed that rely on a probabilistic description of the speckle noise and of the parameters to be estimated from the noisy data.

Speckle noise is the result of two phenomenons, first phenomenon is the coherent summation of the backscattered signals and other is the random interference of electromagnetic signals. Speckle noise degrades the appearance and quality of SAR images. Ultimately it reduces the performances of important techniques of image processing such as detection, segmentation, enhancement and classification etc. That is why speckle noise should be removed before applying any image processing techniques.

There are three main objectives of any speckle filtering. First is to remove noise in uniform regions. Second is to preserve and enhance edges and image features and third is to provide a good visual appearance. Unfortunately 100% speckle reduction is not possible. Therefore, tradeoff has to be made among these requirements. Speckle reduction usually consists of three stages. First stage is to transform the noisy image to a new space (frequency domain). Second stage is the manipulation of coefficients. Third is to transform the resultant coefficients back to the original space (spatial domain).Currently many statistical filters are available for speckle reduction. Such as Mean, Kuan, Frost, Lee and MAP filter etc. Results show that statistical filters are good in speckle reduction but they also lose important feature details. Additionally prior knowledge about noise statistics is a prerequisite for statistical filters.

In recent years, there has been active research on wavelet based speckle reduction because wavelet provides multi resolution decomposition and analysis of image. In wavelet sub bands noise is present in small coefficients and important feature details are present in large coefficients. If small coefficients are removed, we will get noise free image.

PROBLEM DOMAIN:

High quality images of Earth produced by synthetic Aperture radar (SAR) systems have become increasingly available. However, speckle reduction is one of many factors which impede SAR images to be easily interpreted, thus remains a major issue in SAR image processing.

Synthetic aperture radar (SAR) imaging, due to its powerful imaging capability in all weather conditions, day and night, sunny and cloudy, has become more and more popular in our daily lives and in military tasks. But unfortunately, speckle noise, caused by the coherent imaging, makes interpretation & analyzing of SAR images very difficult. So the goal of preprocessing in SAR images is to remove the multiplicative speckle noise and to preserve all texture features efficiently.

Synthetic aperture radar is a radar technology that is used from satellite or airplane. It produces high resolution images of earth's surface by using special signal processing techniques. Synthetic aperture radar has important role in gathering information about earth's surface because it can operate under all kinds of weather condition (whether it is cloudy, hazy or dark).However acquisition of SAR images face certain problems. SAR images contain speckle noise which is based on multiplicative noise or Rayleigh noise. Speckle noise is the result of two phenomenon, first phenomenon is the coherent summation of the backscattered signals and other is the random interference of electromagnetic signals. Speckle noise degrades the appearance and quality of SAR images. Ultimately it reduces the performances of important techniques of image processing such as detection, segmentation, enhancement and classification etc. That is why speckle noise should be removed before applying any image processing techniques.

2. OVERVIEW

Speckle model for SAR images:

Speckle noise is typically modeled as multiplicative noise (Rayleigh noise), therefore final output signal is the product of original signal and speckle noise

Let I (i, j)be the degraded pixel of an observed image and S (i, j)is the noise-free image pixel to be recovered. With the multiplicative noise model,

$I\,(i, j) = S\,(i, j) * N\,(i, j)$

In which N (i, j) represents the multiplicative noise with unit mean and standard deviation.

Most of researchers convert multiplicative noise into additive noise by homomorphic filtering before speckle filtering of SAR images. But research shows that there is no significant impact of homomorphic filtering on any speckle filtering Algorithm. So it is not necessary to convert speckle noise to additive noise. Additionally, mean of log transformed speckle noise does not equal to zero. Therefore necessary corrections and adjustments have to be made before any further processing. So homomorphic filtering is not recommended step for speckle filtering.

A. Directional Smoothing

During despeckling, edges are blurred so to protect edges from blurring directional smoothing filter is used.

- Select mask of size 3×3 or 5×5 or 7×7
- Take the average of pixels of each direction as shown in Figure and store in array v(n) where n =4

  $$\frac{1}{\sum_i \sum_j y(m-i, n-j)}$$

- Find V1(n) such that

  $$V_1\,(n) = \text{abs}\,(v\,(n) - x(r,c))$$

  For each mask. Where x(r,c) is central pixel of mask.
- Find index of V1(n) that gives minimum value such that Index= min (V1)
- Replace the pixel value of x(r,c) by v(index)

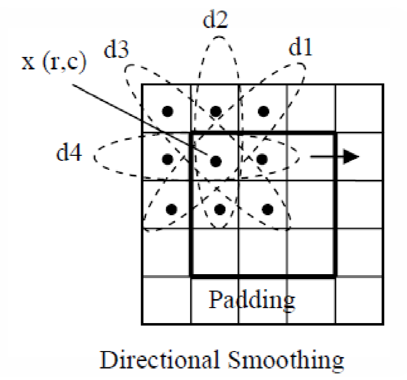


Fig.1 Directional Smoothing

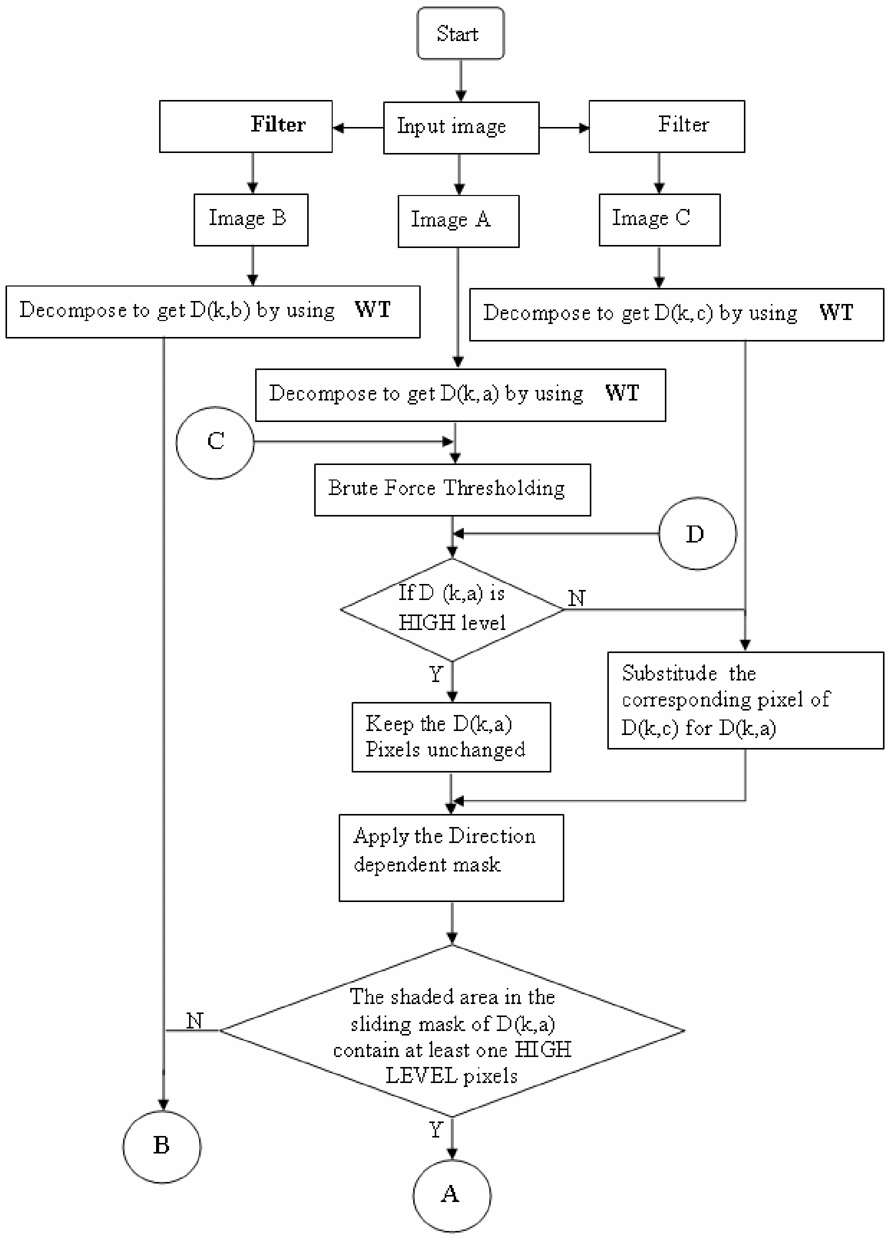
- Repeat the whole procedure until whole image is scanned by mask.

B. Brute Force Thresholding

Brute force thresholding always outclass other existing thresholding techniques in terms of better results. Algorithm for brute force thresholding is given

- Input wavelet sub band.
- Find maximum (max) and minimum (min) value of sub band coefficients.
- loop through (threshold=min to max) and execute desired algorithm
- save the results in array for each loop such that F= [threshold,result]
- When loop completed, select the (threshold) that gives best result.

Block Representation


Start
Input image
Filter
Filter
Image B
Image A
Image C
Decompose to get D(k,b) by using WT
Decompose to get D(k,c) by using WT
Decompose to get D(k,a) by using WT
C
Brute Force Thresholding
D
If D (k,a) is HIGH level
N
Y
Substitude the corresponding pixel of D(k,c) for D(k,a)
Keep the D(k,a) Pixels unchanged
Apply the Direction dependent mask
The shaded area in the sliding mask of D(k,a) contain at least one HIGH LEVEL pixels
N
Y
B
A

Continues...

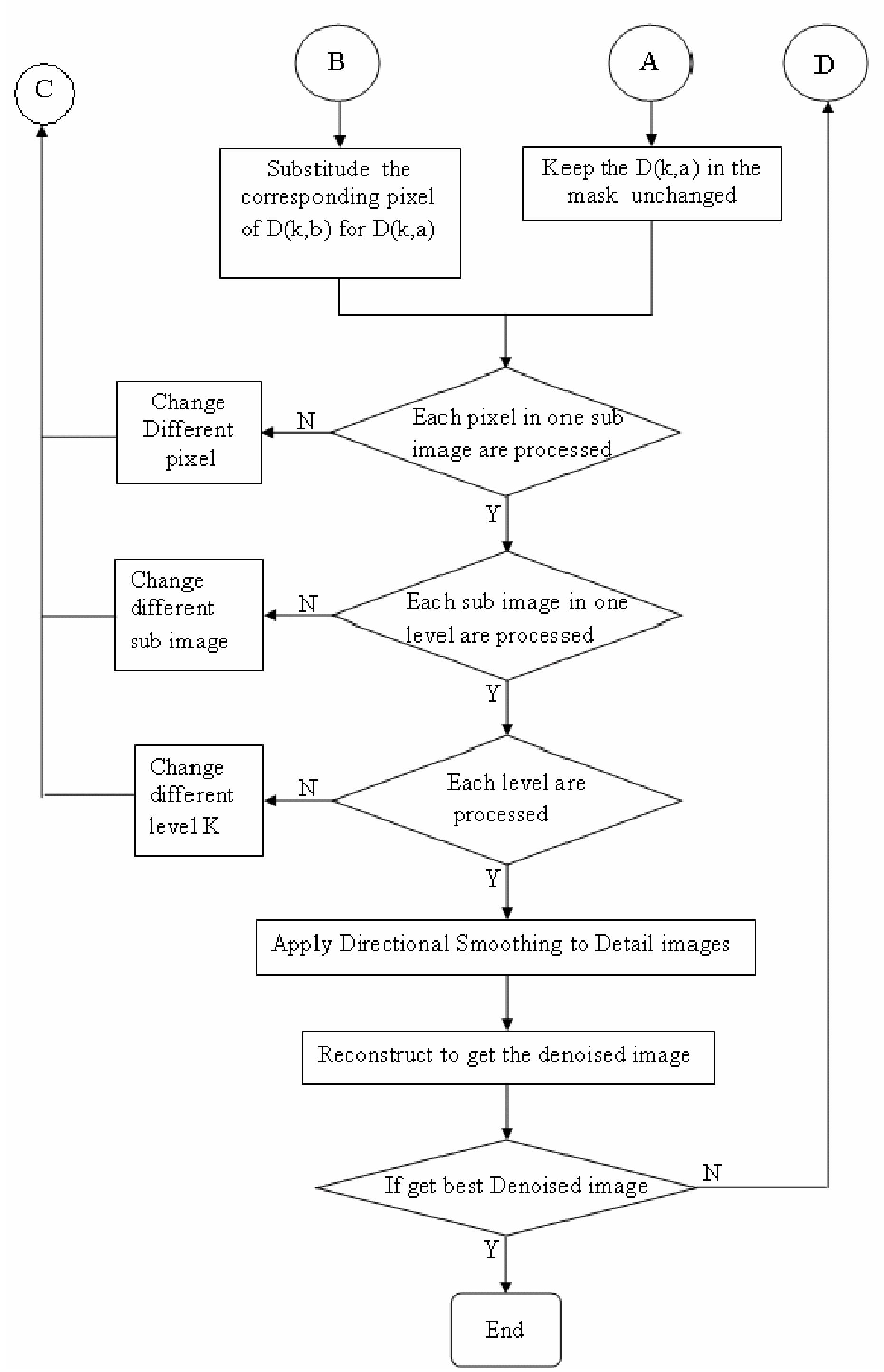
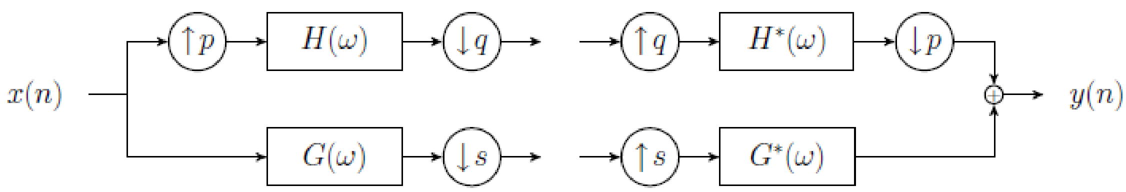


Fig.2:Block representation

Proposed Algorithm:

In particular, we take up the design of systems that are analogous to Daubechies orthonormal wavelets. That is, the design of minimal length wavelet filters satisfying certain polynomial properties, but now in the oversampled case. The wavelets are constructed using maximally at perfect reconstruction filters in conjunction with spectral factorization and extension methods for para unitary matrices. The rational-dilation wavelet transform is based on this filter bank:



$$Y(\omega) = \sum_{k=0}^{q-1} L_k(\omega)\, X\left(\omega + p\, k\frac{2\pi}{q}\right) + \sum_{k=0}^{s-1} M_k(\omega)\, X\left(\omega + k\frac{2\pi}{s}\right),$$

Where,

$$L_k(\omega) = \frac{1}{p\,q}\sum_{n=0}^{p-1} H\left(\frac{\omega}{p} + k\frac{2\pi}{q} + n\frac{2\pi}{p}\right) H^*\left(\frac{\omega}{p} + n\frac{2\pi}{p}\right),$$

$$M_k(\omega) = \frac{1}{s}\left[G\left(\omega + k\frac{2\pi}{s}\right) G^*(\omega)\right].$$

There is no perfect reconstruction filters with rational-transfer functions unless the filter bank is orthonormal (p+1=q=s).

Perfect reconstruction is attained by

$$H(\omega) = \begin{cases} \sqrt{pq} & |\omega| \le \left(1 - \frac{1}{s}\right)\frac{\pi}{p} \\ 0 & |\omega| \in \left[\frac{\pi}{q}, \pi\right] \end{cases} \qquad G(\omega) = \begin{cases} 0 & |\omega| \le \left(1 - \frac{1}{s}\right)\pi \\ \sqrt{s} & |\omega| \in \left[\frac{p}{q}\pi, \pi\right] \end{cases}$$

3. EXPECTED OUTCOME

Algorithm performance will be evaluate with the help of following assessment parameters.

A. Mean Square Error (MSE)

MSE indicates average square difference of the pixels throughout the image between the original image (speckled) Id and Despeckled image Id. A lower MSE means that there is a significant

$$MSE = \frac{\sum (Is(r,c) - Id(r,c))^2}{R \times C}$$

filter performance. But small MSE values did not always correspond to good visual quality.

Where R*C is the size of image.

B. Peak Signal to Noise Ratio (PSNR)

The PSNR is most commonly used as a measure of quality of reconstruction in image compression and image denoising etc. The PSNR is given by

$$PSNR = \frac{10LOG(255)^2}{MSE}$$

Greater the value of PSNR, better the speckle reduction of images. Based on these two parameters, the outcomes with the research will prove it as a better technique for denoising SAR images as compare to the existing technologies.

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