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Research Article

Speckle Suppression Method for SAR Image

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Abstract: In this study, a new speckle reduction method was proposed in terms of by Bidimensional Empirical Mode Decomposition (BEMD). In this method, the SAR image containing speckle noise was decomposed into a number of elementary components by using BEMD and then the extremal points are done the boundary equivalent extension after screening and the residual continue to be done the boundary equivalent extension until screening is completed, finally, the image was reconstructed, which reduced the speckle noise. Experimental results show that this method has good effect on suppressing speckle noise, compared to the average filter, median filter and gaussian filter and has advantages of sufficiently retaining edge and detail information while suppressing speckle noise.

Keywords: BEMD, noise suppression, SAR image, speckle noise

INTRODUCTION

Synthetic Aperture Radar (SAR) images are widely used, due to it uses the way of the coherent imaging mode, the speckle noise caused by the target echo signal fading process, seriously affect the quality of the SAR images .Therefore, improving and suppressing the speckle noise become an important guarantee to obtain a coherent view of the high quality for the SAR image.

In recent years, many scholars proposed some speckle noise suppression methods which can be broadly divided into two categories: multi- looking before imaging and filtering technology after imaging. The former is based on the cost of reducing spatial resolution, to suppress the speckle noise before imaging processing, the latter is divided into two branches of the spatial filtering techniques and frequency-domain filtering techniques, frequency domain filtering technique is based on the Fourier transform technology which the relationship between speckle noise and data to remove speckle noise (Lee, 1980); Spatial filtering technique is based on a random speckle noise of the SAR within a sufficiently small range through all pixels within that range average to remove speckle noise and decompose the image into different frequency components in the frequency domain to remove the high frequency components to remove noise in the frequency (Huang *et al*., 1998). Algorithm based on spatial filtering technique has now become the mainstream of the SAR image noise suppression technology. Its core is which the data will be decomposed into different composition in airspace, based on the different components of the noise definition and useful data and the data will be decomposed in the spatial domain.

Based on the analysis of statistical characteristics about the speckle, this study proposes the BEMD (Bimensional Empirical Mode Decomposition) filtering algorithm, according to the different inhibition scale of SAR single-look image speckle noise in the spatial domain, the experimental results show that the algorithm has stronger ability to suppress Speckle noise and better keep the image edges and detail information.

THE PRINCIPLE OF THE BEMD ALGORITHM

The Empirical Mode Decomposition (EMD) is the smooth processing for a signal, whose result will gradually decompose the wave of different scales signal or the trend, produce a series of different features scale data sequence, generate a series of a data sequence with having a different characteristic scales which each sequence represents a proper type component IMF (Intrinsic Mode Function) and meet the following two conditions:

- Local extremum number and zero crossing points equal or a difference of up to 1.
- The Mean of upper and lower envelope for the local extremum in arbitrary point on the data is zero.

These two conditions actually represent a fluctuation pattern (Donoho, 1995), most of the time sequence contains a variety of wave mode, the empirical mode decomposition on the basis of the defined sequence of Eigen mode decompose the signal through the screening process (Sifting process) into a series of characteristic scales from the smallest to the largest

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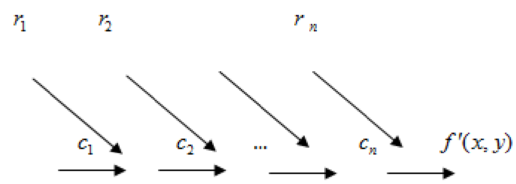


Fig. 1: De-noised image reconstruction processing

increase in the IMF and a trend item margin. Based on the principle of one-dimensional EMD decomposition, it will be expanded to two-dimensional EMD which can be used in image processing. The screening procedure of image BEMD is as follows:

- According to the 8 neighborhood for image local extreme value point, if the two dimensional plane do not have extreme value point, which can appear a maximum point and a minimum point through carrying out an order or order after derivation arithmetic.
- In the image will to be processed $f(x, y)$, interpolating surface constructed by extreme points, solving the algebraic average $E_1(x, y) = (e_{max}+e_{min})/2$ of the maximum enveloping surface e_{max} and the minimum envelope surface e_{min}.
- The difference between the original image data $f(x, y)$ and the average $E_1(x, y)$ is $h_1(x, y)$, namely:

$$h_1(x,y) = f(x,y) - E_1(x,y) \tag{1}$$

- $h_1(x, y)$ is an intermediate process value for $f(x, y)$ and repeat the above process k times, until $h_{1k}(x, y)$ is the first order IMF1 component, there is:

$$h_{1(k-1)}(x,y) - E_1(x,y) = h_{1k}(x,y) \tag{2}$$

- We define $c_1(x, y) = h_{1k}(x, y)$ and then $c_1(x, y)$ which is separated from the first order IMF1 component and then $c_1(x, y)$ is separated from the original data separation, get remainder term $r_1(x,y)$, namely:

$$f(x,y) - c_1(x,y) = r_1(x,y) \tag{3}$$

- We will $r_1(x, y)$ as a new data and repeat the process n times, get the final expression:

$$f(x,y) = \sum_{i=1}^{n} c_i(x,y) + r_n(x,y) \tag{4}$$

where, $f(x, y)$ is the original image data and $c_i(x, y)$ is the smaller-scale details information after decomposition, $r_n(x, y)$ is to get the ultimate scale trend.

The terminal condition of BEMD is still not very clear at present. According to decomposition threshold standard of screening stopping confirmed by Huang *et al*. (1998), it can be realized by limitation of Standard Deviation (SD):

$$SD = \sum_{x=0}^{X}\sum_{y=0}^{Y} \frac{\left[h_{k-1}(x,y) - h_k(x,y)\right]^2}{h_{k-1}^2(x,y)} \tag{5}$$

There is no fixed standard of confirmation of SD value and the general choice is between 0.2 and 0.3 and its value has the direct influence to the decomposition process of BEMD. The smaller the set SD value is, the bigger the number of decomposed IMF is, but the time taken in decomposition process will be rapidly increased (Li *et al*., 2009).

IMF mode function sequence obtained by the above steps scales is from small to large order, image speckle noise components contained in the high-frequency components of the small-scale component, to remove arrangement in the first one or two small scale component and then reconstruct image (Nunes *et al*., 2003), so that to achieve the purpose of speckle noise. Processing is shown in Fig. 1 ($f'(x, y)$ is the de-noised image).

DELAUNAY TRIANGULATION INTERPOLATION METHOD

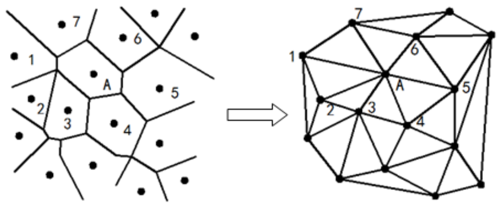
In BEMD decomposition, the envelope average is based on the original data of the upper and lower extreme points which are respectively spline interpolated and fitted and then averaged, in spline interpolation, the extreme value point is scattered distribution, which needs to organize them and curve surface fitting in space (Ramon, 2001).

This study applied Delaunay triangulation interpolation method to realize the envelope surface fitting. The study region is divided into a simple triangle area, interpolation curved surface is structured in every small triangle; further these patches are stitched together and constructed a large the interpolation surface.

For Delaunay edge: suppose E in a side e (a, b are two endpoints), if there is a round through a, b two points, circle does not contain any other point in P, then e is called Delaunay edges. On Delaunay triangulation: if point set P contains a second Angle split T that contains only Delaunay edge, then T is the Delaunay triangulation.

The basic principle of DT method: any given N plane points $P_i(i = 1, 2, \ldots, N)$ and a point set P is constituted, then the convex polygon $S(P_i)$ that meet the following conditions is Voronoi polygon:

$$S(P_i) = \left\{x \in R^2 \mid d\left(x, P_i\right) \le d\left(x, P_j\right); i, j = 1, 2, \cdots, N, i \ne j\right\} \tag{6}$$



(a) Voronoi image (b) Delaunay image

Fig. 2: The example of surface Delaunay triangulation

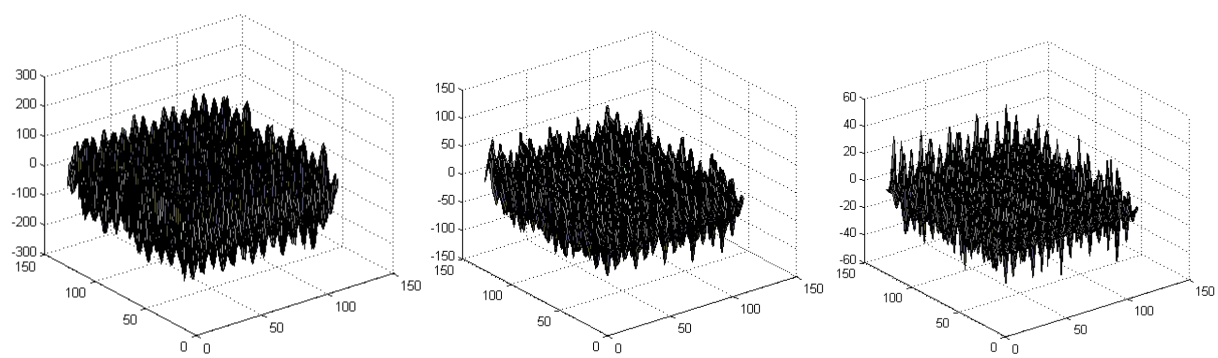
The Voronoi diagram $S(P_1)$, $S(P_2)$, $S(P_3)$, …, $S(P_N)$ will be planed into N convex polygons, $S(P_2)$, $S(P_i)$ are actually the intersection that formed by N-1 half plane with the perpendicular bisector of the plane B and the other N-1 node. A Delaunay triangle will be formed by connecting the polygon node of three vertices polygon, Fig. 2 is a plane subdivision results (the vertices of the triangle is the local extrema points of the image).

Delaunay triangulation has some characteristics of empty circle (arbitrary 4 point can't common circle) and maximizing the minimum Angle, so in all kinds of two-dimensional triangulations, only DT meet both global and local optimum, which can be as much as possible to avoid the formation of the triangle with over the acute angle (otherwise it affects image quality). The plane will be split with the linear interpolation, cubic interpolation or nearest point interpolation combining; then the entire triangulation interpolation process can be completed.

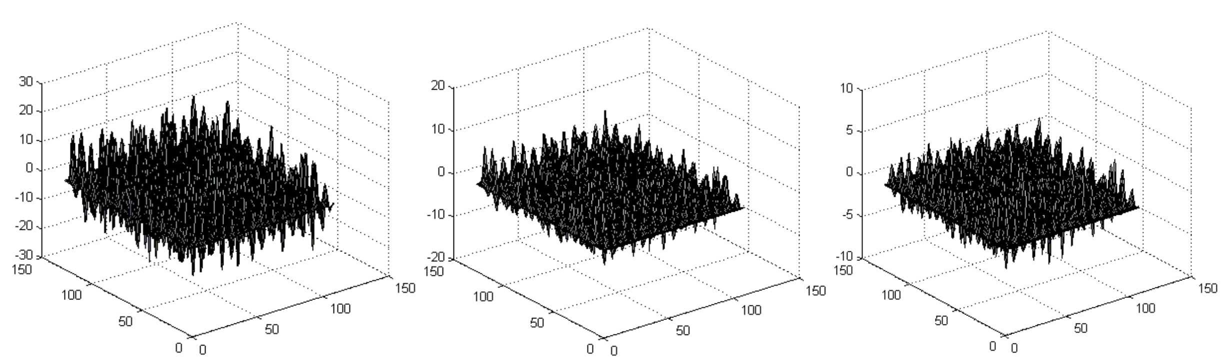
THE EXPERIMENTAL RESULTS AND ANALYSIS

Decomposition of the SAR image: The experiment uses the spaceborne SAR image that is 200×200 noise pollution original experiments and utilizes BEMD method to deal with the noise of the image.

BEMD decomposition process is a natural scale process that the image is separated from the low frequency to the high frequency. The first exploded intrinsic mode components IMF1 contains the highest frequency component of the image (Arsenault and April, 1976), the entire frequency of the component is corresponding to the local maximum frequency of the image in all parts. The original image minus the first layer intrinsic mode components to get the first layer residual; the first layer residual in the decomposition gets the second intrinsic mode components, each layer intrinsic modal component are made by the residual decomposition of above layer residual. The mesh diagram of the BEMD decomposition components is shown in Fig. 3.



(a) IMF1 (b) IMF2 (c) IMF3



(d) IMF4 (e) IMF5 (f) residue5

Fig. 3: The mesh diagram of the BEMD decomposition components

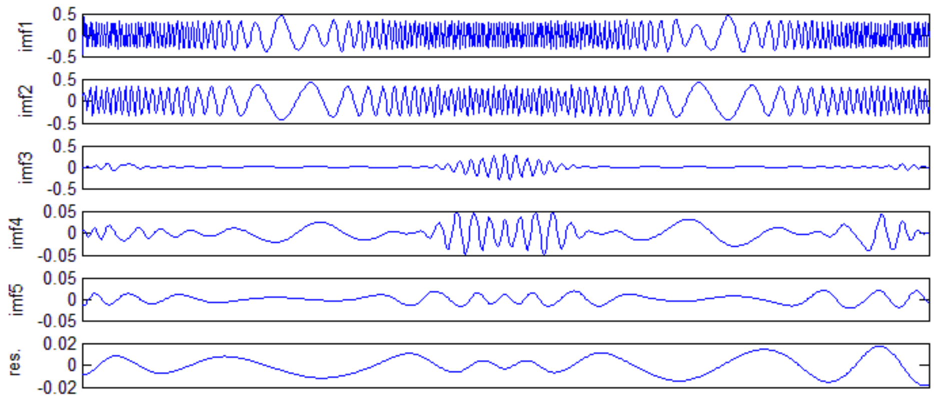
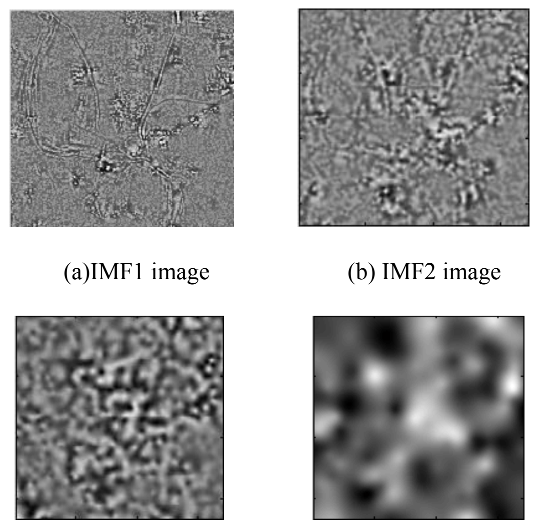


Fig. 4: The BEMD decomposition results of IMF

Figure 4 is a cross-sectional view of the SAR image, the Fig. 4 can be seen that the difference on the low frequency IMF component obtained by BEMD method is large, with the frequency decreasing, whose difference is transmitting from the vicinity of the boundary towards the intermediate of the signal.

It does linear interpolation using Delaunay triangulation, because the decomposed IMF component in the edge has black pollution, the black pollution area increasingly extended to the center of the image, the black side gradually devour the top intrinsic mode components of the image, the decomposition component is shown in Fig. 5.



(a)IMF1 image (b) IMF2 image

(c) IMF3 image (d) IMF3 image

Fig. 5: The IMF component diagram decomposed by BEMD

Analysis of experimental result: This study uses the image quality index of the mean, standard deviation, PSNR, ENL and EPI to compare the filtering effect in order to better compare and analysis the experimental results. The mean value reflects the average gradation of the image, namely it contains an average backscatter coefficient of target; the number of the standard deviation represents the amount of the image information (Lee, 1981); Equivalent Number Of Looks (ENL) is a measure of the relative intensity on the image coherent speckle noise which reflects the inhibition ability of the filter spots, the greater the ENL is, the weaker the coherent speckle of images is, the better the interpretation is, which is defined as follows:

$$ENL = I^2 / \sigma^2 \tag{7}$$

where,

I = The mean of all pixels
σ = The standard deviation

Edge information is an important indicator of the evaluation filter before and after the filtering process changed in the filtering process. Keeping the image edge information that can make the denoising image edge is not blurred and the edge point is not displaced, for the subsequent step of geometric correction, edge extraction and classification has important significance. The higher the Edge Preserving Index (EPI) is, the better the edge-preserving capacity is and the formula is:

$$EPI = \frac{\sum |P_s - P_{sn}|}{\sum |P_o - P_{on}|} \tag{8}$$

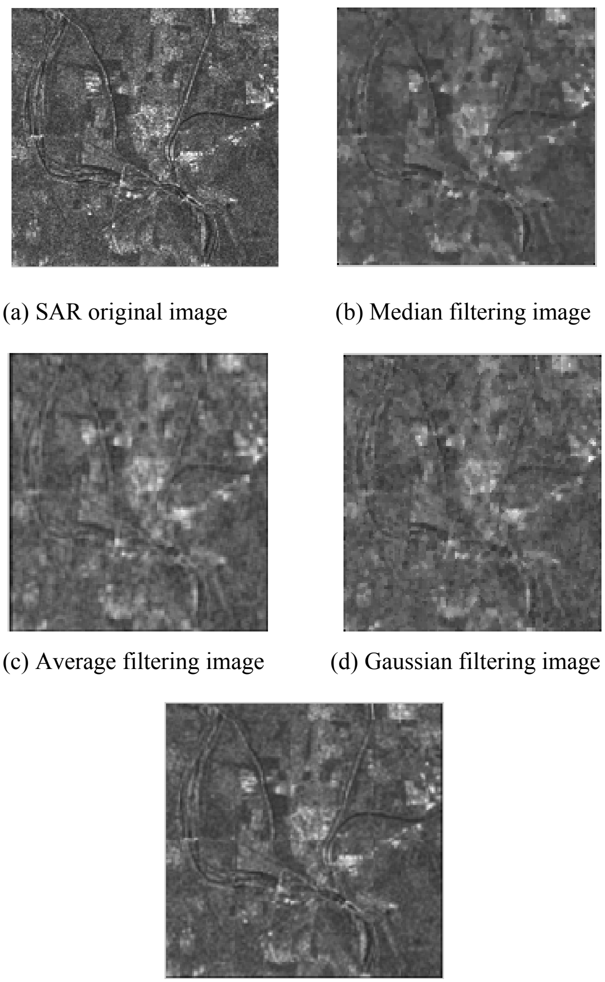
where,

P_s = A pixel value after denoising
P_{sn} = The adjacent pixels of P_s
P_o = The original image pixel values
P_{on} = The adjacent pixels of P_o

The Peak Signal-To-Noise Ratio (PSNR) is based on the minimum mean square error criterion and is also a valid index that measures the noise image quality, the formula for:

Table 1: Comparison of the de-noised effect and the edge retained effect

Denoising method	Mean	S.D.	PSNR	Relative standard deviation	ENL	EPI
Median filtering	93.9442	23.8459	14.4703	0.2538	15.5207	0.6821
Average filtering	92.6848	22.9184	20.1642	0.2473	16.3549	0.6867
Gaussian filtering	99.2094	26.5997	17.1060	0.2681	13.9108	0.7691
BEMD algorithm	91.4909	22.7604	21.9778	0.2488	16.1583	0.7986



(a) SAR original image

(b) Median filtering image

(c) Average filtering image

(d) Gaussian filtering image

(e) BEMD processing image

Fig. 6: Comparison images of the de-noised effect of different algorithms

$$PSNR = 10lg \frac{255^2}{\frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}[f(x,y) - f'(x,y)]^2} \tag{9}$$

where, $f(x, y)$ is the original image, $f'(x, y)$ is the reconstructed image after denoising, M, N, respectively, is the total number of rows and the total number of columns of the image. The size of PSNR can evaluate the quality of the denoising image (Kuan and Sawchuk, 1987), the larger the value of PSNR is, the smaller the distortion between the image and the original image after reconstruction is. The comparison of the de-noised effect and the edge retained effect are shown in Table 1.

From Table 1, it is known that in the above 4 denoising method, the mean of BEMD algorithm is the smallest, the smoothing effect is better, the image is closest to the true value, the relative standard deviation followed by average filtering image is the minimum; in the PSNR, the value of the median filtering is the minimum, the value of BEMD algorithm is the maximum which indicate that different frequency domain signal and noise are well separated by BEMD algorithm and the denoising effect is better; in the EPI and the ENL, the equivalent ability of the EPI and the ENL for the BEMD algorithm are better than other algorithms, the ENL of Gaussian filter is lowest, but the ability of keeping edge is higher than the median filter and the mean filtering. From the above parameters and Fig. 6, it is known that the images of the BEMD algorithm is approximated to the original image from the edge, the details and the texture information or the visual effect; thus it can be seen that the BEMD algorithm is an effective noise suppression method of SAR image. The Comparison images of the de-noised effect of different algorithms are shown in Fig. 6.

CONCLUSION

Based on the denoising principle of SAR image, this study puts forward the SAR image denoising method on BEMD and discussed the denoising effect of BEMD method. From the mean, standard deviation, ENL, PSNR and relative standard deviation, this method considerable keeps the main information of the original image and simultaneously inhibits the SAR image speckle noise at the same time. The experimental results show that while suppressing the speckle noise of the images, the method in this study can better keep the image edge information and is an effective noise filtering method.

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