A CHMT MODEL BASED DE-SPECKLING METHOD FOR SAR IMAGE

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1. INTRODUCTION

Synthetic aperture radar (SAR) is the significant resource of acquiring the land surface information, employed in increasing scales, such as geological prospecting, agriculture yield estimating, flooding monitoring, urban sprawling, and ecological environment survey. Due to applying active coherent illumination mode, an inherent problem, speckle interference, roots in the process of reconstruction from original signal to image. Speckle degrades the spatial resolution of SAR image, and also interferes with the measurement of backscatter coefficient, seriously influences the application of SAR image. Therefore, the research on speckle reduction techniques is all along one of the important subjects in SAR image processing[1].

Generally, filtering techniques can be classified into multi-look processing [2] before imaging and filtering after imaging. The former method procures the speckle reduction effect at the cost of degrading spatial resolution, while the latter is mainly divided into spatial domain filtering techniques and frequency domain filtering techniques. Spatial domain filters typically include mean-filter, median-filter [3], as well as Lee [4], Frost [5], Gamma-MAP [6], and so forth adaptive filter. With respect to frequency domain filtering, Fourier transform method and Wiener filter are both attempted in this aspect. Wavelet analysis theory is increasingly playing a paramount role in SAR image de-speckling, since it holds the flexible multi-scale characteristic.

Contourlet transform [7] is a new extension of wavelet transform in two-dimensional image domain, bearing the properties of multi-resolution, localization, multi-direction, anisotropy, etc., exploiting the own characteristics of two-dimensional signal (i.e. edge, geometric regularity), grasping the direction-edge information in the image. The ultimate result of contourlet transform is virtually a kind of description for the image using line segments basis. According to the thinking of contourlet, a curve can be expressed by a series of rectangles with different directions and different sizes, yet wavelet depicts a curve only by a series of squares with different sizes (i.e. different resolutions). One-dimensional hidden Markov model (HMM) has accomplished a great success in speech recognition, which intrigued people enormous interests to generalize HMM from one-dimensional to two-dimensional, and already applied in various respects of image processing and computer vision, such as de-speckling [8] and image segmenting [9]. Hidden Markov tree (HMT) is a tree shape expression of HMM. The combination of contourlet transform and HMT generates a novel statistical modeling mathematic tool, named contourlet-domain hidden Markov tree (CHMT) [10].

In this paper, a coarse-classification based tying method for the Contourlet-domain Hidden Markov Tree model (CHMT) solution algorithm is proposed to speed up the parameters estimation; and a general SAR image filtering framework, to which any kind of shift-variant transform can be applied, is generated by applying together with the LOG Transform, mean rectification and cycle-spinning, etc. The proposed coarse classification based tying method for CHMT is applied to de-speckle the simulated image and the true SAR image in the general framework, and the result is compared with those of some commonly-used filters. The visual effects and the statistical parameters indicate that the coarse-classification based tying method for CHMT is much faster than the other tying methods, and the CHMT model based de-speckle method can achieve better result than some commonly-used filters.

2. PARAMETER TRAINING OF CHMT BASED ON COARSE CLASSIFICATION

The purpose of tying is supporting enough training data for model training, and the assumption is that the nodes tied possess the same property or statistical characteristic. If the property of each node can be obtained before tying, and the nodes belonging to identical sort are tied, then the accuracy of model training can be enhanced highly. In order to obtain the classification information, in this study, we use K-mean method to perform coarse classification for the coefficients of directional sub-bands at coarse scale, and determine which trees need to be tied according to the classification result, then train the whole image using multi-tree algorithm. Due to classifying for coarse-scale coefficients in advance, hence, after accomplishing tying, there is maximum "similarity" between the tied coefficients, and utilizing this sort of similarity, the convergence speed of model training is advanced.

3. THE CHMT MODEL BASED DE-SPECKLING ALGORITHM

Contourlet transform is a linear transform, hence, image containing additive noise transformed with contourlet can still be denoted by additive noise model

$$y = x + n \tag{1}$$

where, y=CT(Y) is the contourlet coefficient containing noise, x=CT(X) is the contourlet coefficient of original signal, and n=CT(N) is the contourlet coefficient of noise. CT(·) denotes contourlet transform. De-speckling problem can be expressed as: estimating the original image x based the information concerning the noisy image y. First of all, we establish CHMT model for y, and obtain its model parameter by estimating its parameters using coarse-classification tying EM algorithm, then through removing the noise, we can gain the parameter of de-speckled contourlet coefficients. The contourlet coefficient of noise can be gained by Monte-Carlo method [11].

4. GENERAL FRAMEWORK FOR SAR DESPECKLING

The general frame of SAR filtering in this study can be expressed as follows

$$X = \exp\{\frac{1}{L}\sum_{i=1}^{L} Z_{-i}(CT^{-1}[w(CT[Z_i(R(\log(Y)))])])\} \tag{2}$$

where, Y is noisy SAR image, X is filtered image; log denotes logarithmic transform, aiming at change multiplicative noise into additive noise; CT[·] and CT^{-1}[·] are contourlet transform and contourlet inverse transform, respectively; exp{·} is logarithmic transform; L is the time of cycle-spinning. Z_i and Z_{-i} are cycle-spinning transform and cycle-spinning inverse transform, respectively, with step size i, thereby the visual effect distortion probably caused by contourlet transform is eliminated. Cycle-spinning can effectively solve the problem of shift-variant transform, enhancing the visual effect of result image [12-13]. R(·) denotes mean rectification, thereby the rectified result meets the zero-mean Gaussian white noise assumption. This is because the mean of noise is not zero after logarithmic transform [14], yet generally, filtering algorithms are established under the zero-mean Gaussian white noise assumption, especially concerning CHMT model. We often assume that contourlet coefficients are determined by two zero-mean Gaussian mixture distributions, therefore, it is quite necessary to make mean rectification for transformed image. w(·) denotes filtering algorithm, which can use method based CHMT, also can use wavelet soft threshold method, hard threshold method, and so forth methods not meeting shift-invariance transform, this is why we call it "general" framework.

5. RESULTS AND DISCUSSION

In this study, we employed simulated image and SAR image to evaluate the effect of various filters. The simulated image is generated by a QuickBird image added with speckle noise meeting Gamma distribution with variance 0.05 (a normalized value, i.e. given the values distribute between 0 and 1 when adding noise) . We select Radarsat image (C band, HH polarization, spatial resolution 25×25 m^2) as the SAR image. The dimensions of the two images are both 256×256 pixels. The filtering methods include Lee filtering [15] (the filtering window is 5×5 pixels) and wavelet soft threshold (WST), and three CHMT methods under general framework of SAR filtering using different tying algorithms, i.e. multi-tree tying based CHMT (CHMT-M), single-tree tying based CHMT (CHMT-S) and coarse-classification based CHMT (CC-CHMT). We employed, in CHMT model training, two-state and zero-mean mixture Gaussian distribution, '9-7' LP decomposition, pkva directional filter, and three-level contourlet decomposition with the direction number of each level 4, 8, and 16. With respect to filters in wavelet domain, in order to avoid the influence of different wavelet basis, we select the counterpart of contourlet transform '9-7' as wavelet basis, also with three-level decomposition.

The experiments show that the speed of the proposed tying method is higher than the one of multi-tree algorithm and single-tree algorithm. The comparison of the visual effect and statistical index of various methods indicated that, under the SAR filtering framework, the coarse-classification based tying method for CHMT can highly improve the speed of CHMT training algorithm, and the result is better than the other commonly-used filters.

6. REFERENCES

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