MVM BASED SAR IMAGE PROCESSING FOR SHIP POSE ESTIMATION

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1. INTRODUCTION

Synthetic Aperture Radar (SAR) is nowadays widely used in ocean survey and marine management. Taking the leading position of the international trade, shipping transport is calling for an increasing assistance from the remote sensing technology. Spaceborne SAR, as a primary means of remote sensing, is outstanding for its weather condition unaffectedness and a view field of hundreds of kilometers. Consequently, spaceborne SAR image of ocean ships is playing an important role in the areas such as dock resource assignment, shipping route surveillance, wrecked ship searching, and navigation security insurance.

In the general process of SAR image interpretation, an object-containing region of interest (ROI) is firstly selected, in which the object scattering centers are picked out. After that, the pose of the object (represented by the stem-to-stern axis direction) is figured out so that the structure parameters can be evaluated or the template-matching procedure can be carried on. Pose estimation with accuracy and robustness can not only help the parameter estimation but also reduce the searching load in template matching.

Pose estimation is a process to acquire the structural information as a whole from the dispersed scattering centers. Since the ship scattering centers correspond to its particular electromagnetic scattering phenomena, their positions, intensities and even the spatial relationships can imply the ship structure. Accordingly, a good pose estimation calls for two conditions:

- An accurate extraction of scattering centers.
- A thorough exploration of structural information from the scattering centers

Researches showed the essence of scattering center extraction as the 2-dimension complex exponential signal estimation in a noisy environment, which can be solved via Fourier Transform (FT) or the spectral estimation techniques [1]. However, FT and classical spectral approaches are always trapped in a dilemma between the mainlobe widening and sidelobe leaking. The parametric methods, such as subspace decomposition (MUSIC for example) and autoregressive linear prediction, could not give a good estimation unless the observed signal fit precisely the model assumption [2]. Moreover, the estimation is always ruined by sea clutters in nature. Considering the aforementioned factors, the minimum variance method (MVM, also called the Capon method) [2] is chosen here to extract the scattering centers. Besides a precise estimation of the exponential parameters, MVM is famous for its model-assumption independence and sidelobe suppression ability [2].

SAR image processed using MVM shows distinct morphologic features. An Angle Entropy of Radon Transform (AER) technique is hereby designed to explore the directional information of the ship image. Actually, plenty of work has been announced on this topic. For example, JI, et al. [3] use the linear regression strategy to find the line around which the scattering centers distribute. L. I. Voice, et al. [4] evaluate the axis direction by the edge-based Hough Transform (HT) technique. However, these methods, based on either the scattering centers or the edge points, can hardly work effectually in a SAR ocean image. The former is disturbed by the outliers arising from sea clutter, while the latter, though performing well in optical images, turns sensitive to the discontinuity of SAR scattering centers. On the contrary, the AER technique utilizes the region configuration instead of the ship points and therefore achieves a more robust estimation.

2. APPROACHES

For the purpose of sea ship pose estimation, three approaches are respectively implemented in the procedures of SAR image interpolation process.

Firstly, choose the ROI from the original complex image, turn it back to the phase history domain by 2D-FFT, and regenerate an image with the MVM technique. Generally, MVM filters the data to estimate the signal power of a certain frequency. FIR filter coefficients are designed according to the data correlation matrix, allowing the interested frequency power passing with unit gain, and synchronously minimizing the output energy of other frequencies [2]. When used in the SAR imaging processing, MVM images not only hold a good estimation of the scattering centers, but also suppress the sidelobe leaking and sea clutters.

Secondly, sort pixels of the new image by intensity to form the pixel intensity histogram (PIH). Choose a proper pixel threshold from the histogram. All the pixels with higher value are picked out to form the ship region. The rest are regarded as sea clutter area, which is not interested in. MVM image is suitable for such an operation due to its large between-region contrast and small within-region variety.

Thirdly, calculate the RT of the bivalue image for each searching angle $\psi \in [-\pi, \pi]$, and then the Shannon entropy of the transformed data. The angle-dependent value, named AER, is minimized to determine the ship direction. RT computes the integral projection of the image intensity onto a given direction with a slope $\tan\psi$, while the entropy is a measurement of data concentration. The smaller is the AER, the more centralized is the Radon transformed data. Consequently, the minimum AER probably corresponds to the integral along the ship axis.

3. SIMULATIONS AND RESULTS

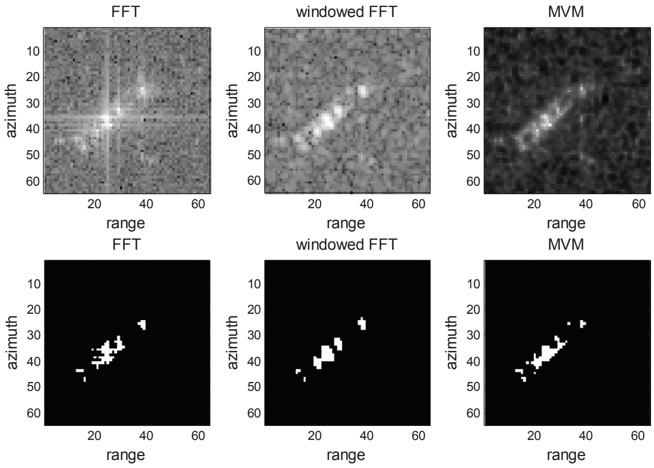
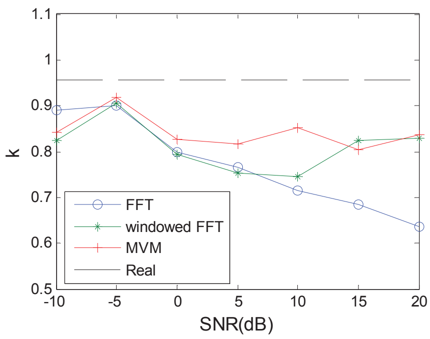
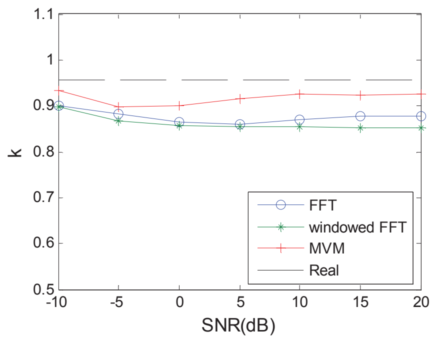


Fig. 1. Ship model images and segmentation results (SNR=10dB)



(a) Edge-based HT technique



(b) AER minimization technique

Fig. 2. Average slopes of the ship axis

Experiments are carried out with the complex RCS of a ship model on a rough surface calculated using computational electromagnetics. White Gaussian thermal noises with $SNR = -10, -5, ..., 15, 20dB$ are added respectively. Experiments firstly compare images generated by 2-D FFT, the Hanning windowed 2-D FFT (HW-FFT) and MVM. Quantities of ship-to-clutter mean value ratio, ship-to-clutter maximum value ratio and the standard deviation of each region are then examined for these images. Afterward, the AER strategy is compared with the edge-based HT approach to estimate the axis slopes of the same ship.

Fig.1 shows an example of ship model images and the segmentation results with SNR=10dB. The above three figures in turn are generated by the methods mentioned above, and the ones below are the segmentation results correspondingly. Neither the sidelobe leaking (as in the FFT image) nor the mainlobe widening (as in the HW-FFT image) apparently appears in the MVM image. Furthermore, it shows a higher contrast and a sharper outline than any of the other images.

Fig.2 gives the average slopes of the ship axis estimated by the aforementioned methods under changing SNRs. The real value deduced from the imaging scene is also given. Apparently, the AER minimization performs better than the edge-based HT technique under all SNR conditions, among which the estimation with MVM image is the best. Furthermore, in Fig. 2(a), the FFT image estimation goes far from the real due to the cross sidelobes. And all the estimation show a downward bias caused probably by the scatter asymmetry (see Fig. 1).

4. CONCLUSIONS

As an essential approach of SAR image interpolation, a good pose estimation calls for two conditions: an accurate extraction of scattering centers and a thorough exploration of structural information from the scattering centers. This article focuses on these two topics successively. The MVM is introduced to improve the scattering center resolution and an AER minimization strategy is designed for the axis extraction. Data from computational electromagnetics are used in experiment, where the MVM image shows more distinct morphologic feature than the 2D-FFT ones, and the AER minimization estimation is more accurate and robust than the edge-based HT technique.

5. REFERENCES

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