Application of ship wakes detection trace of Synthetic Aperture Radar (SAR) image in the rights protection of coast guard

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Abstract: The current situation of rights protection of the coast guard in China is lack of the monitoring capacity especially in a wide range using the ship-borne equipment. Compared with shore-based, ship-borne, airborne detection devices, visible light and infrared remote sensing, SAR has the advantages of coverage widely, stable platform, long-term continuous observation, and high input-output ratio. The common methods of ship information extraction based on SAR images include direct detection of ship targets, detection of ship wake characteristics and detection of oil film on sea surface caused by engine or fish oil leakage. Several algorithms have been developed for ship wake detection, including two-parameter constant false alarm rate (CFAR) algorithm, K-distribution based CFAR algorithm, multi-polarization detection algorithm and multi-image correlation method. In this paper, combining the needs of marine rights enforcement and analyzing the characteristics of different algorithms and, the ship wake information extraction technology of SAR image is applied to the marine integrated management and control network to improve the recognition rate of ship target monitoring, expand the monitoring scope, shorten the analysis and recognition time, and effectively enhance the law enforcement capability of marine rights protection in China. Strength, safeguard China's marine rights and interests.

1. Introduction

Marine enforcement capability is an important guarantee for building a strong maritime power and safeguarding China's marine rights. Information identification of ship targets is a very important part of marine rights enforcement [1]. Correct, rapid and accurate identification of ship targets under our jurisdiction plays an important role in improving the ability of marine rights enforcement.

FIGURE 1. Stereoscopic management and control network schematic diagram

The current situation for rights protection in China is lack of the monitoring capacity, and the ship-borne equipment cannot monitor all-weather in a wide range [2]. Therefore, space-based is an important part of the integrated ocean management and control network, which mainly includes

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remote sensing and ocean satellites. Compared with shore-based, ship-borne, airborne detection devices and visible and infrared remote sensing, space-borne synthetic aperture radar (SAR) has wide coverage, stable platform, long-term performance, continuous observation, high input-output ratio, legality of satellite detection and low-orbit satellite launching[3]. Moreover, based on target and track characteristics of the ship and Doppler frequency shift information, ship detection technology of SAR is very sensitive to changes of sea surface structure It can be all-weather and all-time high [4]. The resolution can be used to image the ship's position, shape (geometric size), type, direction, and speed. According to the different backscattering sensitivity of rough surface, it can be used to identify ocean features and ship targets at sea, so it can be used as an important means of monitoring large-scale ship targets at sea.

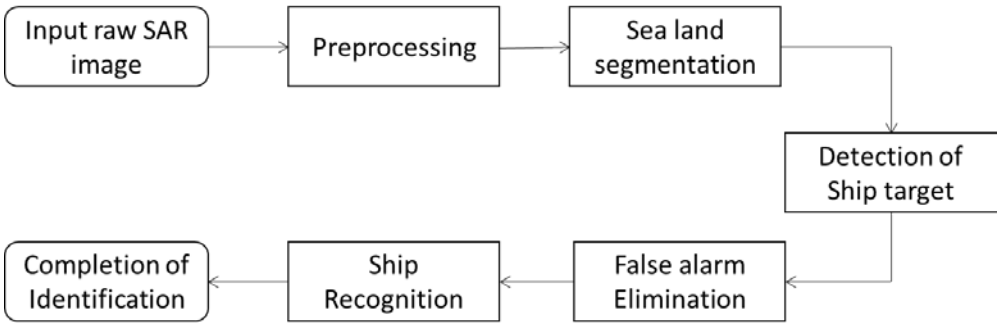


FIGURE 2. Process of ship target detection

The methods of ship information extraction based on SAR image include direct detection of ship targets in SAR image, ship wake features and oil film on the sea surface caused by engine or fish oil leakage [5]. Previous studies showed that ship wake has a longer time and larger space scale than ship. When the ship has left the target area, SAR image can catch obvious wake characteristics [6]. The main advantages of SAR are the larger scale and a higher accuracy contract the direct wake information with the converted three-dimensional image.

2. METHOD

Four types of ship wakes are observed in SAR images, turbulence wake, Kelvin wake, narrow V-shaped wake and ship generated internal wave wakes（see in Tab.1） [6]. Detection of wakes in SAR image can be used to retrieve the speed and course information of moving ship and help find the small and weak ship targets which are difficult to detect in the image.

Through the analysis of research status at home and abroad, combined the needs of maritime rights enforcement in China, we compared the advantages and disadvantages of different methods and adaptability, and summarized the wake information extraction methods suitable for the current situation.

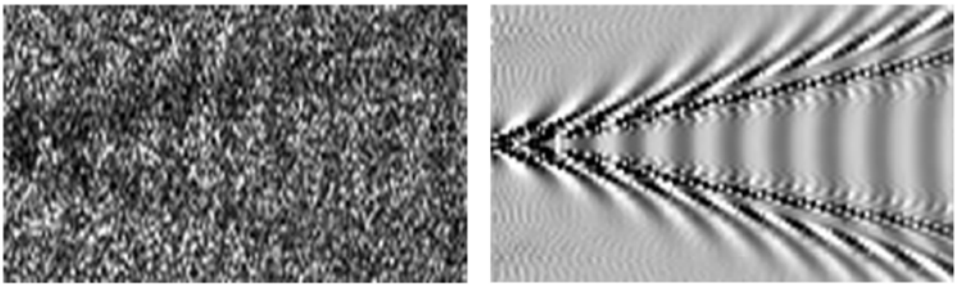
TABLE 1. Classification and characteristics of ship wake

Characteristics of sea wake		Representation in SAR image	Mechanism of wake imaging	Wake angle
Surface wave	Prague wave	Narrow V-shaped bright line	Bragg effect	Included angle＜10°
	Kelvin trail	Kelvin arm	Tilt and Hydrodynamic modulation	Included angle=39°
Turbulent or eddy wake		Dark stripe	Flow field and inhibition	Near axis
Internal waves generated by ships		Internal wave wake	Flow field effect	Depends on speed

3. Results and Discussion

3.1 Current Research Situations

At present, the construction of marine three-dimensional network in foreign countries started earlier and updated frequently to improve the overall monitoring level. In the aspect of space-based, the space surveillance system of the United States had the advantages of unlimited by geographical location, worked all day, guarded wide area space, detected, and tracked small targets in deep space. For the identification of ship targets, several target monitoring systems had been established, including the Alaskan SAR demonstration and verification (AKDEMO) system in the United States, the ocean monitoring workstation (OMW) system in Canada[7], the global environment and safety monitoring framework (GMES) of the European integration project and the mast system of QinetiQ in the United Kingdom. Many algorithms have been developed in ship wake detection, including two parameter CFAR algorithm, K-distribution based CFAR algorithm, multi polarization detection algorithm and multi-image correlation algorithm. M. yeremy (2001) [8] used radarsat-1 satellite data and multi polarization algorithm to detect warships near the Canadian sea area. The results showed that suitable structure classification detected polarization signals more effective.



(a) (b)

FIGURE 2. (a) The image of ship wake captured by SAR (b) The image of ship wake by simulated

In 2001, involved the aspect of target recognition in SAR image extraction wake information, Wang Shiqing[9] proposed an algorithm SWDRM for ship wake detection by Radon transform and morphological image processing technology. The results showed that this method applied in different levels of noise environment. Binary image could get automatic wake detection combined with image post-processing. In 2003, Zhang Yu [10] reviewed the overall research methods of ship and wake detection technology in SAR image and evaluated various detection methods at present. In 2015, Huang Jiaqi [11] studied the SAR simulation technology based on the current situation of wake detection, simulated and simulated different ship wake by modeling.

3.2 Discussions

On the basis of comparison and analysis (Generation mechanism see in Fig.3), the methods started from the shape characteristics of ship wake and turned to the problem of line feature detection under the speckle noise. Some form of filtering pretreatment and strong scattering point removal were carried out for the image firstly to eliminate the influence of the speckle noise when used the line detection method based on Radon transform or Hough transform. There are many methods to preprocess SAR image before detecting the ship wake, including sliding window filter, wavelet correlator, random matching filter, normalization of de mean, singularity elimination, median filter, mean-shift filter, and nonlinear filter so on.

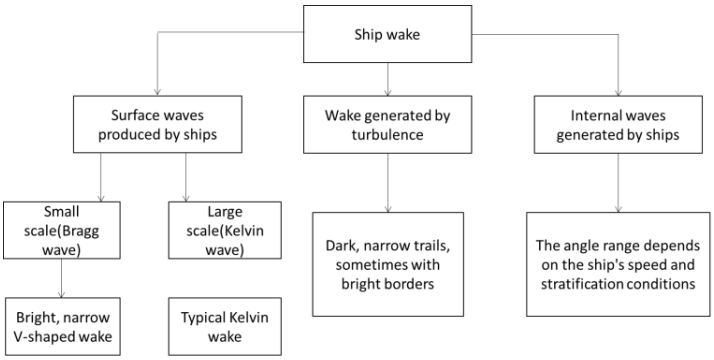
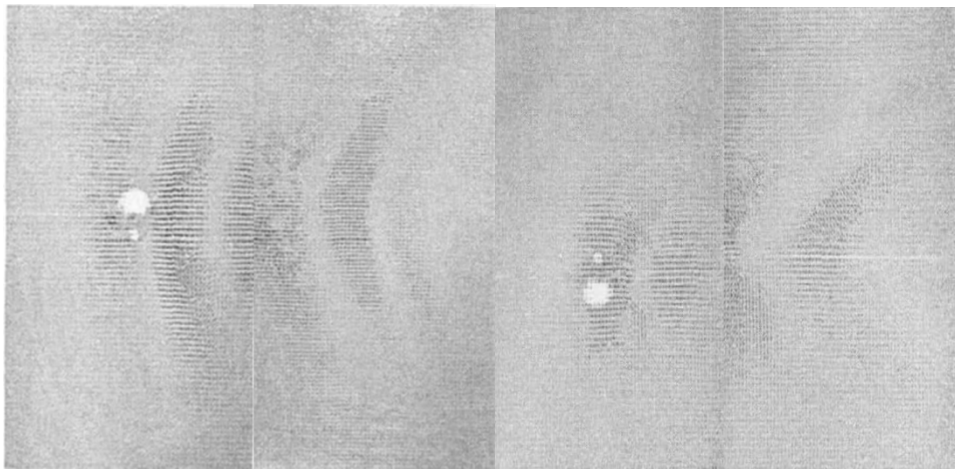


FIGURE 3. Generation mechanism of ship wake

Experiments (see in Fig.4) showed that with the increase of speed, the wake range first increased and then decreased. When the speed was very large, the wake range increased again. This showed that the actual inversion of ship parameters based on wake characteristics was not only affected by the environment, but also by its own speed. On the contrary, some researches didn't advocate the image preprocessing, but thought that radon transform, or Hough transform itself has the ability of speckle noise suppression. We chose standard radon transform method, length normalized Radon transform method, window Radon transform method, line segment Radon transform method and so on in the wake detection stage after preprocessing. So, when dealing with the problem, we should choose the appropriate method according to the situation of the local sea area.



(a) (b)

(a)Low velocity (b)High velocity

FIGURE 4. Ship wake image simulated by PIV

4. Conclusion

The ocean condition is complex and changeable and the image of various wake in SAR are very different. The existing methods of ship wake in SAR image have better effect in simple sea background, but they are difficult to meet the requirements in complex sea background. In conclusion, there are many methods which have their own advantages and disadvantages. It must be combined with the actual situation, and the complex sea conditions put forward higher requirements for the method.

Combined the methods of ship target recognition in SAR image, we found two problems: (1) Reliability of simulated SAR image data. At present, the research of image ship recognition was mostly based on simulation data, which is not rigorous enough to verify the effectiveness of recognition methods; (2) Overall effectiveness of features. A single type of feature could not describe the ship target effectively.

As follows is the development trend of tailing information extraction methods suitable for the current situation. It is necessary to establish the wake imaging model through different types of wake features in SAR. For better results, we should consider various sea conditions. The parameters of the ship target are studied on the basis of the study of the parameters of the wake. The ship parameter estimation is studied in depth according to the wake matching test criteria.

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