HIGH-RESOLUTION OPTICAL SATELLITE IMAGE SIMULATION OF SHIP TARGET IN LARGE SEA SCENES

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ABSTRACT

Ship target detection in optical remote sensing images has attracted more and more attention in the field of remote sensing. The ship target detection technology of optical remote sensing images is vulnerable to many factors, while the real data are difficult to contain various elements. In order to obtain the various situations in the large sea scenes, we develop a simulation system for high-resolution optical remote sensing image of ship targets. The simulated images with different sea states, cloud conditions, target types and imaging conditions can support the evaluation and comparison of ship detection algorithms as well as other tasks in remote sensing image analysis.

***Index Terms*—** Satellite image simulation, ship detection, remote sensing, image analysis

1. INTRODUCTION

Ship detection in remote sensing images plays an important role in both military and civil fields. It is essential for maritime security, traffic management, naval warfare and other applications [1]. The performance of ship detection based on synthetic aperture radar (SAR) images is limited due to noisy response, low resolution, and long revisit cycle [2]. High resolution optical remote sensing images contain much more detailed information of ships, thus ship detection in optical remote sensing images has attracted more and more attentions in recent years [3, 4, 5, 6]. To solve the problem of ship detection in high-resolution optical images, the existing methods are based on classifier learning [3], threshold segmentation [4], shape and texture features [5, 6], etc. Researchers have shown promising results on their own sets of images, whereas those datasets have various resolution, image size and background. High-resolution optical satellite images suffer from many issues, such as weather condition, ocean waves, and imaging time. These issues are important for performance evaluation of ship detection methods. However, it is difficult to obtain enough sea scene images of different conditions for qualitative and quantitative evaluations and comparisons for ship detection approaches.

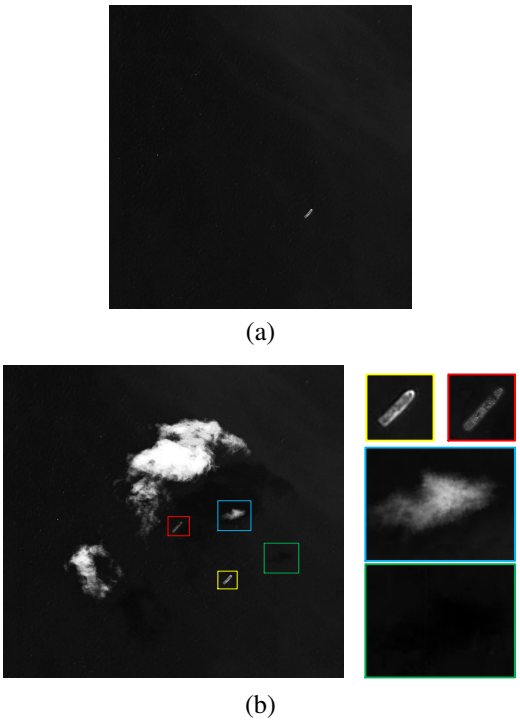

Fig. 1: (a) A high-resolution panchromatic optical image; (b) simulated image including ship targets. (yellow box) a true ship target; (red box) a simulated ship target; (blue box) a piece of cloud; (green box) cloud shadow.

Image simulation is a feasible way to solve the problem of data lack. Some simulation methods were proposed to simulate infrared images [7] and SAR images [8], but few works have been done for optical images. In this paper, we propose a complete process for simulating high-resolution panchromatic images of ship targets in large sea scenes. We focus on ships in sea scene since the inshore images of ships can be easily collected. Our simulation method considers serval key elements that affect ship detection, including clouds, shadows, islands, waves, ship types, etc., and can facilitate future evaluation and comparison of ship detection algorithms. Besides, the images simulated by our method can also be applied

to other tasks in remote sensing image analysis, such as cloud detection, shadow removal, image quality assessment, ship recognition, etc.

The rest of this paper is organized as follows. Section 2 introduces the challenges in ship detection, including weather condition, imaging condition and target property. Section 3 describes the process of our simulation method. Section 4 presents the applications of the simulated images. Finally, Section 5 comes to the conclusion.

2. DIFFICULTIES OF SHIP DETECTION

In high-resolution optical satellite images, ship detection usually is disturbed by three factors, namely weather condition, imaging condition and target property.

Weather condition in sea area mainly includes sea state and cloud condition. Sea state level indicates different complexity of sea surface. Sea surface is quiet in level 0 with no waves and few interferences (Fig. 2(a)). There will be more visible swells and interferences when the sea state level increases (Fig. 2(b)), possibly leading to a major loss and false alarms in ship detection. Cloud condition can be divided into cloudlessness, thin cloud and thick cloud. Cloudless images are most suitable for detection, while thin clouds may influence the gray scale distribution of whole image (Fig. 2(c)) and thick clouds may occlude the targets and change their features (Fig. 2(d)).

Imaging condition primarily contains imaging time and MTF (Modulation Transfer Function). The images captured in the morning and dusk (Fig. 2(e)) are dimer than those collected in the noontime. Likewise, images in summer (Fig. 2(f)) are brighter than those in winter. The detection performance is also easily impacted by underexposed or overexposed condition. The synthetical response for sensor during of imaging process can be considered as an MTF. In this paper, we only focus on image noise (Fig. 2(g)) and image blurring (Fig. 2(h)).

Ship targets are manmade objects with a long bar and symmetrical shape (Fig. 2(i)). Most ships in sea area are moving targets and have long wakes. Taking the advantage of long and bright wakes of the ship, regions of interest including ships could be deduced. Since ships and wakes are connected and sometimes of the same gray value, precise detection may become a tough challenge. Another key problem is that ships have plenty of types and different courses, therefore the features adopted in ship detection should be scale and rotation invariant. When a ship is occluded or with low contrast, missing detection rate tends to be high. Meanwhile, false alarms often contain broken clouds, sea waves, ship wakes and small islands.

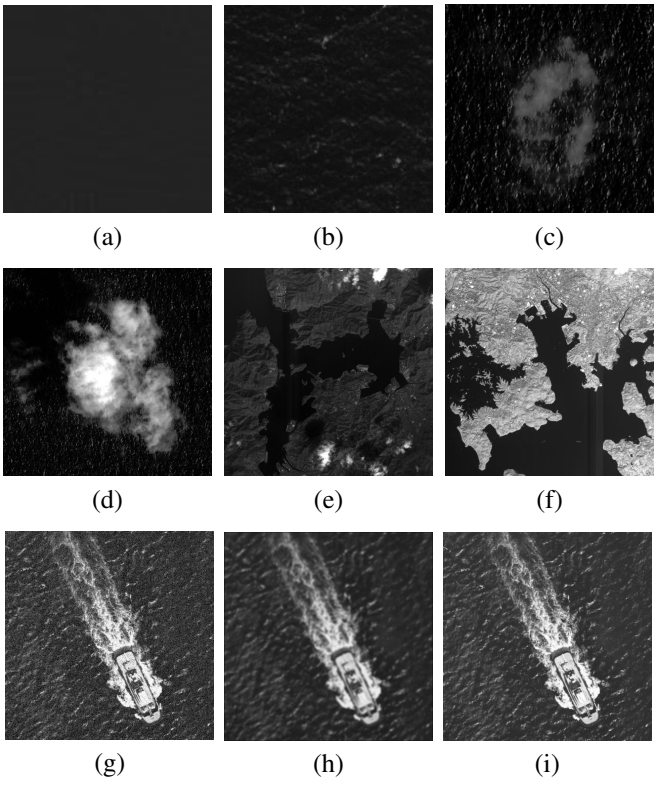

Fig. 2: Optical remote sensing images under different conditions.

3. METHODOLOGY DESCRIPTION

The issues mentioned above lead to a large number of technical difficulties in automatic ship detection. Unfortunately, there are not enough high-resolution optical satellite images to support algorithm analysis and comparison. For this reason, we propose a high-resolution optical satellite image simulation system based on image synthesis. Fig. 3 shows the framework of our simulation method, while Fig. 4 displays some supporting fundamental images containing various sea surfaces, ship targets and clouds, which are collected from Gaofen-1 and Gaofen-2 satellite images to enforce the reality of the simulated images.

As seen in Fig. 3, in the first step of our simulation method, we select a sea surface image at a certain sea state level as the background. Then according to the required task, some ship targets are overlaid in the background images. Those ships may have diverse sizes and courses, and the types that can be simulated include carrier, frigate, destroyer, container, cargoship, oil tanker and small boat. To simulate cloud condition, cloud slices with different quantity, area and transparency can be added. The quantity and area reflect the cloudage, and the transparency corresponds to the thickness of the clouds. Finally, in order to simulate reality images, the method should simulate the true imaging condition. We

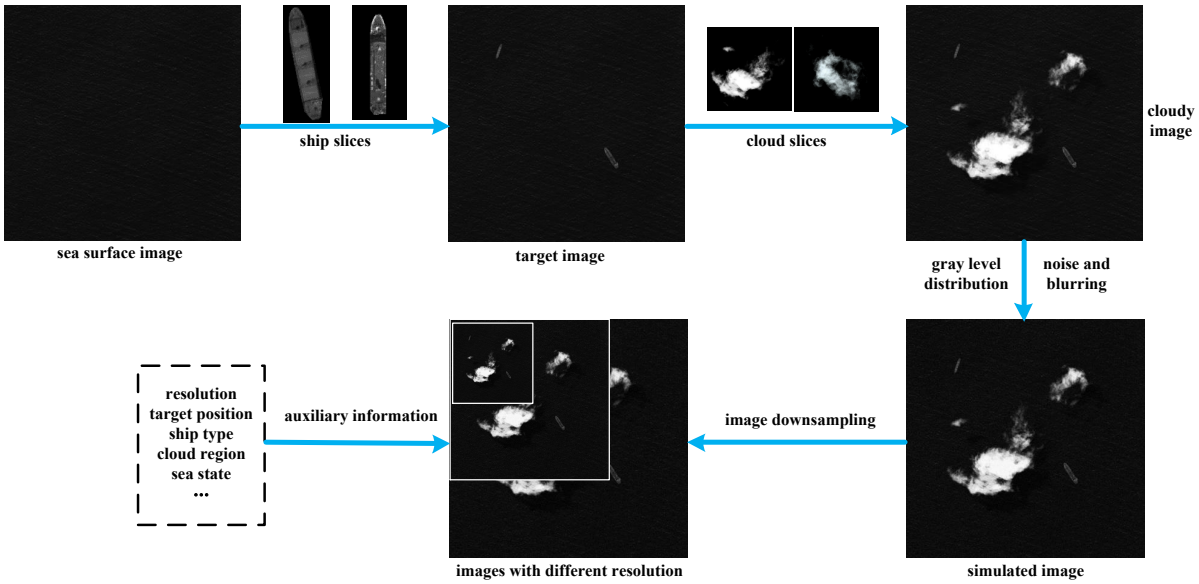

Fig. 3: The framework of the simulation method.

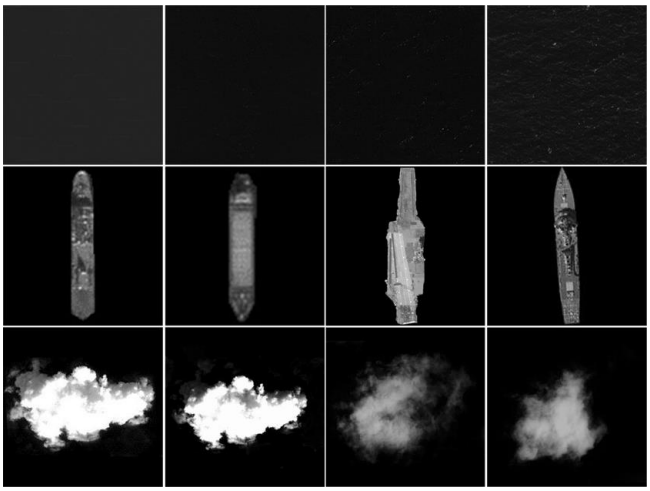

Fig. 4: Some supporting fundamental images. From top row to bottom row: sea surface, ship target and cloud samples.

adjust the the overall gray level distribution to simulate the imaging time. Meanwhile, Gaussian noise and blurring are added for simulating image degradation. In addition, images with different resolution can be obtained by image downsampling, and all auxiliary information of the simulated image is saved for further use, including image size and resolution, the ground truth of ship targets' location and type, image quality, sea state and cloud condition. A simulated image is shown in Fig. 5.

4. APPLICATIONS

We have developed a simulation system according to the framework and applied in ship detection. To validate our method, we collect 100 images in 2-m resolution (50 satellite images and 50 simulated images). The image size is 1024×1024. We perform the ship detection approach in [9] on this dataset. Results are shown in Table 1. We can see that the method [9] gets similar recall and precision on the real subset and the simulated subset, meaning that a method will perform similarly on real remote sensing data and our simulated images. This demonstrates the feasibility and practicability of our method. Thus our method can be used to generate standard data for evaluation and comparison of ship detection algorithms. Besides, the simulated images can be also used for other applications, such as ship recognition, course estimation, cloud detection, shadow removal and image quality assessment.

5. CONCLUSION

In this paper, we utilize image synthesis to simulate high-resolution optical images of ship targets in large sea scenes. The complete simulation chain takes weather condition, imaging condition and target property into consideration. The simulated images produced by the simulation system cover most of the situation in sea area and can supply the evaluation and comparison of ship detection algorithms. The experiments on real and simulated panchromatic satellite images demonstrate the effectiveness of the proposed method.

Table 1: Detection performance comparison between satellite images and simulated images.

Image group	Total number of ships	Number of detected targets	Number of detected real ships	*Recall*	*Precision*
Satellite images	84	82	72	85.7%	87.8%
Simulated images	84	83	74	88.1%	89.2%

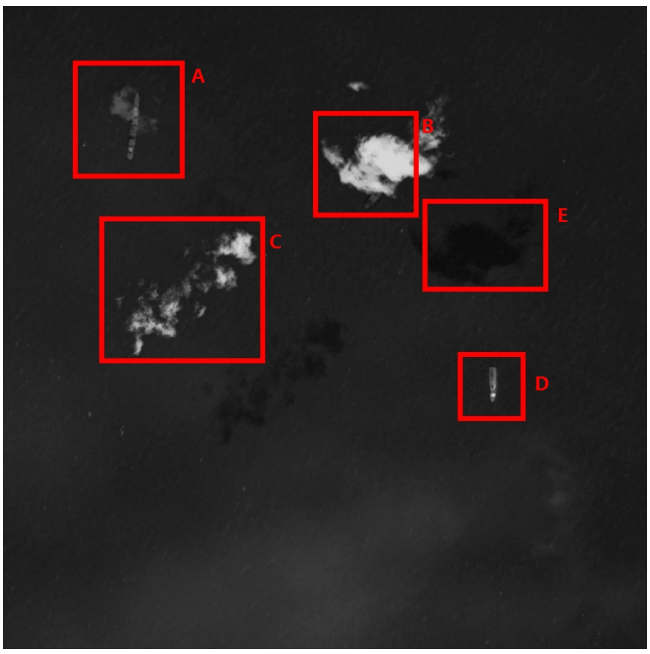

Fig. 5: A simulated image. (A) thin cloud (B) occlusion (C) cloud (D) ship target (E) shadow

We believe that our method can facilitate the research of ship detection in optical images and has a wide application to other remote sensing image analysis tasks.

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