해양 영상에서 선박으로 인한 후류 영역 탐지 기법

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Ship Wake Detection Algorithm for Maritime Optical Images

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Abstract

We propose a novel algorithm for detecting ship wake trails in optical images of the maritime environment. The proposed algorithm first removes the sky region by localizing the horizon to prevent false wake trails detection. Then, a feature map is computed by employing brightness distortion and chromatic distortion. The feature map is thresholded to obtain a rough estimate of wake trails. Finally, the wake map is refined using the shape prior information. Experimental results show that the proposed algorithm can effectively detect wake trails in images.

1. Introduction

Automatic surveillance systems for the maritime domain are becoming more critical due to the increase of commercial ocean liners and other seafaring vessels, such as naval ships or cruise ships. However, images of the maritime environment include lots of clutters, such as ship wakes. Therefore, it is important to design an algorithm that can identify the presence of ship wakes to improve the quality of image processing applications in the maritime environment.

Several approaches for ship wake detection have been developed. However, most of the algorithms were designed for synthetic-aperture radar images, which are of low resolution. Although a few wake detection techniques for optical images have been developed, they focused on ship detection and ignored other regions in the images.

To address this limitation, we propose a ship wake detection algorithm in optical images of the maritime environment. First, the sky region in the image is removed to avoid false detection. Then, a feature map is obtained using brightness distortion and color distortion. Finally, prior information for the shapes of the ship wakes is used to refine the wake map. Experimental results show that the proposed algorithm effectively detects ship wake trails.

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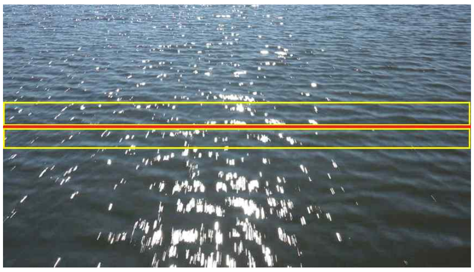


Figure 1. The horizon does not exist in this example.

2. Proposed Algorithm

Because the sky has similar visual properties with wake trails, we first detect the horizon and removes the sky region. We employ a conventional horizon detection algorithm [1]. However, an input image may contain sea region only; hence we add an additional step to verify the existence of the horizon. The similarity between two patches P and Q from both sides, divided by the detected horizon, is computed using the Hellinger distance as

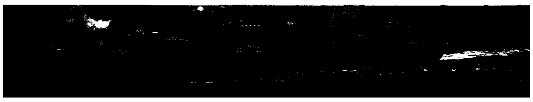
$$H_D(P,Q) = \sqrt{1 - \sum_{u=1}^{M} \sqrt{p_u q_u}} \quad (1)$$

where p_u and q_u denote the probability distribution functions of the patch P and Q, respectively, and M is the number of histogram bins. The horizon does not exist if $H_D(P,Q) < 0.25$, which is shown in Figure 1.

Then, we estimate the wake regions only in the sea region. Let R be the obtained sea region from the previous step. For each pixel $I \in R$, the brightness distortion and chromatic distortion between

(a)

(b)



(c)

Figure 2. (a) Feature map, (b) result of the Otsu's method, and (c) result of the modified method.

I and W are computed as [2]

$$B(I,W)=\left|\frac{I\cdot W}{\|W\|}-\|W\|\right| \tag{2}$$

$$C(I,W)=\cos^{-1}\left(\frac{I\cdot W}{\|I\|\times\|W\|}\right) \tag{3}$$

where W denote the absolute white pixel in the RGB color space. Next, we compute the feature map $F(I)$ using the brightness distortion and chromatic distortion, given by

$$F(I)=B(I,W)^{\gamma_1}\times C(I,W)^{\gamma_2} \tag{4}$$

where $\gamma_1>1$ and $\gamma_2>2$ are user-controllable parameters.

Next, we apply thresholding to the feature map to obtain a rough estimate of the wake map. We employ the Otsu's method [3] for adaptive thresholding. However, as shown in Figure 2(b), when the histogram is bimodal, Otsu's method provides poor results. To overcome this weakness, we normalize the histogram, and then repeatedly increase the threshold t until

$$var(\{H_t,H_{t+1},\ldots,H_{t+50}\})<0.05 \tag{5}$$

where H_t is the histogram value for t.

Finally, we exploit prior information on the shapes of wake trails to eliminate false detections. The movements of seafaring vehicles create curvy or long and narrow wake trails. To take advantage of these properties, we perform polynomial fitting of order 1 (lines for long wake trails) and 2 (parabolas for curvy wake trails) on each connected component of the thresholded feature map. A connected component is considered as a part of a wake trail if the line or parabola fitting error is less than 10% of the width of the input image.

3. Experimental Results

We evaluate the performance of the proposed ship wake detection algorithm using a set of 20 test images. These images were taken under various lighting conditions. The distance from the camera to the ships varies. We fix the parameters γ_1 and γ_2 in (4) to 2.0 and 10.0, respectively.

(a) (b)

Figure 3. Experimental results. (a) Input images and (b) detected wakes.

Figure 3(b) shows the detection results for the input images in Figure 3(a). The images in the top row and middle row show results for the bright scene a low luminance scene, respectively. The images in the bottom row show the input and the corresponding detection result when the camera is far from the sea surface and the sky is brighter than ship wakes so that the wake trails are very thin compared to the size of the image. We see that the proposed algorithm effectively detects the wake trails.

4. Conclusions

We proposed a novel algorithm for detecting ship wake trails in optical images of the maritime environment. The proposed algorithm first removes the sky region, and then a feature map is computed by employing brightness distortion and chromatic distortion. The feature map is thresholded to obtain a rough estimate of wake trails. Finally, the wake trails are refined to provide the final results. Experimental results showed that the proposed algorithm can effectively detect wake trails under various conditions.

References

[1] D. Liang and L. Ya, "Horizon detection from electro-optical sensors under maritime environment," *IEEE Trans. Instrum. Meas.*, accepted in Feb. 2019.

[2] W.-C. Hu, C.-Y. Yang, and D.-Y. Huang, "Robust real-time ship detection and tracking for visual surveillance of cage aquaculture," *J. Vis. Commun. Image Represent.*, vol. 22, no. 6, pp. 543-556, Aug. 2011.

[3] N. Otsu, "A threshold selection method from gray-level histograms," *IEEE Trans. Syst., Man, Cybern. Syst.*, vol. 9, no. 1, pp. 62-66, Jan. 1979.