Infrared Physics & Technology 76 (2016) 185–199

Contents lists available at ScienceDirect

Infrared Physics & Technology

journal homepage: www.elsevier.com/locate/infrared

# Automatic detection of sea-sky horizon line and small targets in maritime infrared imagery

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H I G H L I G H T S

- Gray level feature of maritime infrared imagery is studied.
- The equation of the sea-sky horizon is set up by examining the approximate image based on Haar wavelet decomposition.
- The target is extracted by the method of mutual wavelet energy combination.
- Noises are suppressed by dividing the energy imagery into strips according to the distance to the sea-sky horizon line.

A R T I C L E I N F O

*Article history:*
Received 9 August 2015
Revised 26 January 2016
Accepted 26 January 2016
Available online 27 February 2016

*Keywords:*
Maritime background
Small targets
Sea-sky horizon line
Wavelet decomposition
Standard deviation
Mutual wavelet energy combination

A B S T R A C T

It is usually difficult but important to extract distant targets from sea clutters and clouds since the targets are small compared to the pixel field of view. In this paper, an algorithm based on wavelet transformation is proposed for automatic detection of small targets under the maritime background. We recognize that the distant small targets generally appear near the sea-sky horizon line and noises lie along the direction of sea-sky horizon line. So the sea-sky horizon is located firstly by examining the approximate image of a Haar wavelet decomposition of the original image. And the equation of the sea-sky horizon is set up, no matter whether the sea-sky horizon is horizontal or not. Since the sea-sky horizon is located, not only the potential area but also the strip direction of noise is got. Then the modified mutual wavelet energy combination algorithm is applied to extract targets with targets being marked by red windows. Computer simulations are shown to validate the great adaptability of the sea-sky horizon line detection and the accuracy of the small targets detection. The algorithm should be useful to engineers and scientists to design precise guidance or maritime monitoring system.



## 1. Introduction

Infrared small target detection is one of the most crucial techniques in automatic target recognition. The infrared targets to be detected in the distance are usually small, dim and embed in the real clutter background. With the increases of demand for remote detection, small infrared targets detection is always an extremely challenging task. Benefiting from its valuable outputs, small target detection technology is widely applied in military reconnaissance, early warning and terminal guidance, etc. [1].

The recent work by Olson et al. [2] has demonstrated the usefulness of wavelet analysis and tailored dictionaries for improving the automatic detection of small watercraft in infrared imagery in cluttered maritime environments. Teutsch et al. [3] present a way of fusing three different detection approaches taking benefit from their specific advantages to reconstruct measurements, if a split or merge situation is recognized. The resulting split and merge handling shows better results than using each detection approach individually without fusion. Chen et al. [4] present an effective small target detection algorithm inspired by the contrast mechanism of human vision system and derived kernel model. Yilmaz et al. [5] detect the targets in forward looking infrared imagery by using fuzzy clustering, edge fusion and local texture energy. Lu et al. [6] present a method that an edge detector combining with a median filter are used to seek for the sky-sea line and the objects in the images. According to the features of ship targets in sky-sea background, a criterion is set up to distinguish the small ship target from other object.

In this paper, we address the detection of infrared small maritime target. In such situation, the scene imagery is composed of targets which are small, having relatively few pixels, embedded

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http://dx.doi.org/10.1016/j.infrared.2016.01.016
1350-4495/

in the sea-sky background clutters. It is common sense that the remote small targets under the sea-sky background generally appear near the sea-sky horizon line [7]. So the sea-sky horizon should be got firstly to get rid of the most of irrelevant sea-sky background clutters and confirm the potential area where the distant maritime targets in infrared images usually appear. Cao et al. detect the sea-sky line by gradient examination and energy accumulation algorithm [8]; Huang et al. detect the sea-sky line by Hough transformation [9]. The methods above can detect the sea-sky horizon accurately when the infrared image is legible but make some mistakes when there are amounts of sea clutters and cloud noises. As to the small target detection methods, there are many researchers work on it. Background estimate and frame difference fusion method are put forward by Lei and Zhijian [10]. Wang proposes a new target detection algorithm based on image region division and wavelet inter-sub band correlation [11]. Ondini et al. [12] use template-matching techniques for automatic detection of multiple, extended, and low contrast targets in infrared maritime scenarios. Since there are no geometric and structure character to be used, the traditional methods are no longer suitable for small remote targets detection. To develop a general sea-sky horizon line detection method and to improve adaptability of infrared small maritime targets detection, we put forward the new strategy of two steps, flow diagram is shown in Fig. 1:

- Sea-sky horizon line detection. The wavelet coefficients of the original image at approximate sub band, combined with edge detection and the statistical approach, are used to detect the sea-sky horizon line. We suppose that the IR sensor, used for the application, is installed on a ship. The distributed state of the sea-sky horizon, oblique or horizontal, is judged firstly by plot of standard deviation along the columns of the Haar based approximate sub imagery. And the middle point of the oblique or horizontal sea-sky line is confirmed in different ways: oblique line by pixels connectivity and horizontal line by the position of the peak point of the plot of standard deviation along the columns. The slope of the sea-sky horizon line is the optimal value chosen from the slopes between middle point of the sea-sky horizon line and the other edge-points in the binary image operated by Prewitt based edge detection. As the middle point and the slope are both figured out, the equation of the sea-sky horizon is set up.
- Small maritime targets detection. The modified method of mutual wavelet energy combination is used to extrude the small targets. The maritime targets are labeled by red rectangles where the energy is higher than the threshold. In order to suppress background clutter, energy image is divided into three regions, the sea region, the sky region and the horizon line region. And different region applies different noise suppression strategy. In sea region, image erosion templates, the sizes of which are changing according to the distances to the sea-sky horizon line, are applied to erode the energy image. In sky region, the shape and texture features are used.

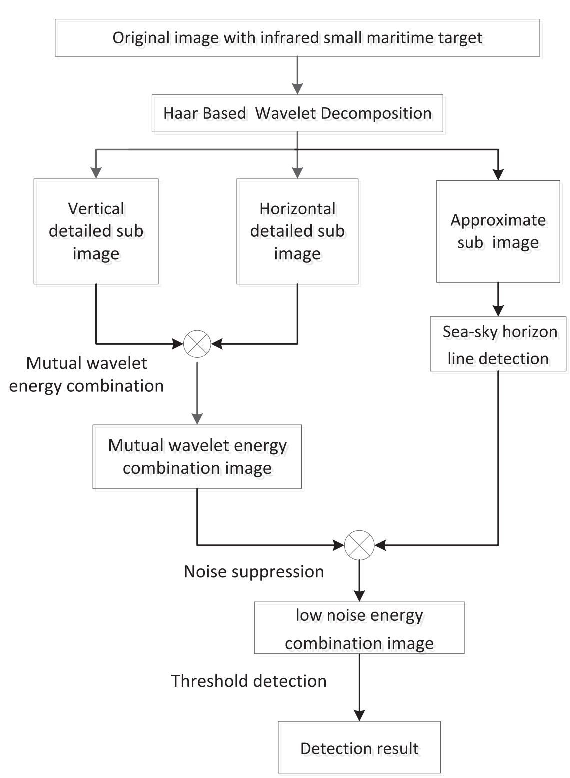

**Fig. 1.** General flow diagram of the detection of infrared distant maritime targets.

Compared with traditional methods, the sea-sky horizon line can be located accurately in heavy noise or mobile platforms with high adaptability in this paper. And different kinds of noise in infrared sea-sky background image has been studied and suppressed. Sea clutter and clouds noise, which are be weaken from a long spread distance, often exists on the lower part of sea surface and the upper part in the sky in infrared image. In addition, maritime scenes are not always only composed of sea and sky but also sometimes include land with man-made structures acting as clutters. The mutual wavelet energy combination image is decomposed into strips according to the distances to the sea-sky horizon line. Different strips use templates with different sizes to erode in sea region. With different kinds of situation considered, the small infrared distant maritime targets detection algorithm is robust and effective.

This paper begin with the flow diagram; then the algorithm of sea-sky horizon line detection is described, and the mutual wavelet energy combination principles for small maritime targets detection is introduced; Finally experiment results are shown to verify the effectiveness of the proposed algorithm.

## 2. Algorithm principle

In this section, the flow diagram is shown first in Section 2.1, then the basic algorithm principles of wavelet transform is presented in Section 2.2, finally the algorithm of sea-sky horizon line detection and infrared small maritime target detection proposed in this paper are elaborated in Sections 2.3 and 2.4 respectively.

### 2.1. Flow diagram

General algorithm flow is shown in Fig. 1.

### 2.2. Wavelet transform

Wavelet transform is a time–frequency localization analytical method with time and frequency windows changing. Namely, there are high temporal resolution and low frequency resolution in the high frequency part, and here are high frequency resolution and low temporal resolution in the high frequency part, and it has the adaptability to different signals [13].

Haar wavelet has the advantages of simpleness, speediness, orthogonal reversible character and compact structure [14]. So we choose Haar wavelet in this paper.

The mother wavelet of Haar wavelet is as follow: