Research on Tracking Approach to Low-flying Weak Small Target near the Sea

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ABSTRACT

Automatic target detection is very difficult in complicate background of sea and sky because of the clutter caused by waves and clouds nearby the sea-level line. In this paper, in view of the low-flying target near the sea is always above the sea-level line, we can first locate the sea-level line, and neglect the image data beneath the sea-level line. Thus the noise under the sea-level line can be suppressed, and the executive time of target segmentation is also much reduced. A new method is proposed, which first uses neighborhood averaging method to suppress background and enhance targets so as to increase SNR, and then uses the multi-point multi-layer vertical Sobel operator combined with linear least squares fitting to locate the sea-level line, lastly uses the centroid tracking algorithm to detect and track the target. In the experiment, high frame rate and high-resolution digital CCD camera and high performance DSP are applied. Experimental results show that this method can efficiently locate the sea-level line on various conditions of lower contrast, and eliminate the negative impact of the clutter caused by waves and clouds, and capture and track target real-timely and accurately.

Keywords: Sea-level line, Target tracking, Sobel, Linear least squares fitting

1. INTRODUCTION

The weapon systems with rapid response are required in modern high-tech war. The effective attack will not be implemented unless targets are timely found, captured, tracked and locked. To find target as early as possible and to make sure that the recovery weapon system has enough response time, the target should be found in long distance. In this process, the detection and tracking of weak small target are key steps for the whole tracking system [1]. In more time, the target is in the form of small target, and its contrast is usually very low. It is extremely difficult to reliably and stably detect and track target [2]. Therefore, the research on detection and tracking approaches to small target with lower contrast has great significance for improving battle distance and response speed of modern high-tech weapons. Especially, automatic target detection is more difficult in complicate background of the sea and sky with the clutter caused by waves and clouds nearby the sea-level line. Small target detection and tracking with lower contrast is also difficult problem of targets recognition at all times. Now there are many research approaches, such as neural network[3], the wavelet transformation[4], likelihood ratio detection[5] and the image flow[6] and so on. But these methods with much computation time and complicated computation are very difficult for hardware implementation, and can not cater to the need of real-time signal processing in the practice application.

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Because low-flying target near the sea is always above the sea-level line, we can first locate the sea-level line, and then segment, capture and track target only above the sea-level line. Thus the executive time of target segmentation is much reduced, and the noise under the sea-level line can be also suppressed. As a result, it increases the capture and track probability and reduces the false alarm.

2. TARGET CHARACTERISTIC

When the target of imaging is far, the light intensity of target received by imaging sensor is very small, and the interference of noise and background is greatly strong, which lead SNR of the image be lower. Furthermore, the target has not clear characteristic of the contour and configuration, so the available information is less.

It is not suitable to adopt the correlation tracking algorithm for the low-flying weak small target near the sea, because the target is very small, and has not clear characteristic. It is also not suitable to adopt the centroid tracking algorithm, because the fly height is lower, the sea-level line can appear in the field of view, and the weather is very complicated on the sea. According to computing (atmospheric refraction and visible distance formula of the sea target), the target usually appears above sea-level line, so we can first locate the sea-level line, and then segment, capture and track target only above the sea-level line. Thus can suppress negative impact of sea background for target tracking, reduce computation time, and increase probability and stability of the capture and tracking. Visible distance formula of the target on the sea is given by

$$D = 2.08(\sqrt{e} + \sqrt{h}) \quad , \tag{1}$$

where D is in sea mile measurement, e is tracker's lens height, and h is target height, their measurements are both mile. Stadia is the distance from the observer to the sea-level line (h =0). For instance, if the target height is 5 miles, and the tracker' lens height is 10 miles, then visibility distance D is equal to 11.2 sea miles, namely 20.7 kilometers (1 sea mile = 1.842 kilometers), which can satisfy the requirements of currently task

3. LOCATINE SEA-LEVEL LINE

Because of the influence of complicated weather and the equipment focus factors, the sea-level line generally appear a band whose brightness becomes gradually lower from the sky to the sea. Moreover, the sea-level line is sometimes fuzzy, and is sometimes clear. If the tracker is on the ship, the sea-level line can be tilted in the field of view. We should adequately consider preceding these factors when locate the sea-level line. Thereby we need special edge detection algorithm to detect sea-level line. One method[7]is presented that the histogram mapped by the row is used to locate the sea-level line, but it is only available to simple background of the sea and sky, and it is also difficult to confirm the threshold of forming binary image. Another method[8] is presented that first each row pixels is averaged, then the position of maximal gradient along column is sea-level line, but this method does not consider that the sea-level line is tilted, and neglect negative impact of the clutter caused by waves and clouds. The Ref. 9 ameliorates Ref. 8, and combines gradient idea with linear fitting, but it is not suitable to detect fuzzy sea-level line. In this paper, we use the multi-point multi-layer vertical Sobel operator combined with linear least squares fitting to locate the sea-level line, and get better effect.

3.1. Linear Least Squares Fit

Let line equation be

$$y = Ax + B , \qquad (2)$$

ON the condition of the LMS[10] (Least Mean square Error), by the equation array

$$\begin{bmatrix} N & \sum_{i=1}^{N} x_i \\ \sum_{i=1}^{N} x_i & \sum_{i=1}^{N} x_i^2 \end{bmatrix} \begin{bmatrix} B \\ A \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^{N} y_i \\ \sum_{i=1}^{N} x_i y_i \end{bmatrix} ,$$

where N is number of (x, y),

so A and B can be written as

$$A = \frac{N\sum_{i=1}^{N} x_i y_i - \sum_{i=1}^{N} x_i \sum_{i=1}^{N} y_i}{D} , \qquad (3)$$

$$B = \frac{\sum_{i=1}^{N} x_i^2 \sum_{i=1}^{N} y_i - \sum_{i=1}^{N} x_i \sum_{i=1}^{N} x_i y_i}{D} , \qquad (4)$$

where

$$D = N\sum_{i=1}^{N} x_i^2 - (\sum_{i=1}^{N} x_i)^2 , \qquad (5)$$

substituting (3), (4) and (5) into (2) can get specific line equation.

3.2. Muti-point Multi-layer Vertical Sobel Algorithm

Sobel edge operator[11] is often used in digital image processing that consisting of (a) and (b) convolution kernel in Fig. 1. Each pixel of the image respectively convolves with (a) and (b), then maximum is output at this point. (a) responds most intensive to vertical edge, and (b) responds most intensive to horizontal edge.

-1	-2	-1
0	0	0
1	2	1

(a) Sobel vertical edge operator;

-1	0	1
-2	0	2
-1	0	1

(b) Sobel horizontal edge operator

Figure 1. Sobel edge operator

Usually, the ship hull will be tilted, but the gradient is very little. If the sea-level line appears in the field of view, we may detect it though vertically taking some columns data, so vertical Sobel algorithm is adopted. Because the sea-level line is not always clear, multiple layers Sobel is adopted. muti-point multi-layer vertical Sobel operator is based on (a) in Fig. 1. One layer vertical Sobel operator is (a) in Fig. 1, and two layers Sobel vertical edge operator and three layers Sobel vertical edge operator are given in Fig. 2. By analogy Fig. 2, we can guess four layers Sobel vertical edge operator, five layers Sobel vertical edge operator, and so on.

-1	-2	-1
-1	-2	-1
1	2	1
1	2	1

(a) Two layers Sobel vertical edge operator;

-1	-2	-1
-1	-2	-1
0	0	0
1	2	1
1	2	1

(b) Three layers Sobel vertical edge operator

Figure 2. Multi-layer Sobel vertical edge operator

3.3. the Line Equation Establishment of the Sea-level Line

Let sea-level line be (2), and we can seen from above (3), (4) and (5) that the key step of locating sea-level line equation is computing position coordinates (x_i , y_i) of sea-level line. First we divide the digital image into M parts (multi-point) along row, then each part is computed by multi-point multi-layer Sobel vertical edge operator respectively, lastly the coordinates (x_i , y_i) (i = 1, 2, … , M) can be computed. The specific computation process is as follows: now we give m part as an example, and let grey level difference of the sky and the sea be T near sea-level line. An conclusion is drawn that maximal layer of multi-point multi-layer Sobel vertical edge operator be less than five or equal five, in accordance with the experiments. We use one, two, … , five layers Sobel vertical edge operator in order, and will stop computing when computation result is bigger than T. The computation row number is y_m . Consequently, position coordinates (x_m , y_m) are obtained.

Some position coordinates (x_i , y_i) are inaccurate for the image of complicate background of the sea and sky, and will have effect on the sea-level line fitting. The method of eliminating inaccurate points is given by

$$\overline{y} = \frac{1}{M}\sum_{i=1}^{M} y_i \quad , \tag{6}$$

Modificatory y_i is

$$y_i = \begin{cases} y_i & \text{if } \overline{y} - \lim it < y_i < \overline{y} + \lim it \\ \overline{y} & \text{else} \end{cases} \quad , \tag{7}$$

where

limit is a constant (usually 10 $\leq$ limit $\leq$ 15).

By making use of (2), (3), (4) and (5) we may establish sea-level line equation, after get position coordinates (x_i , y_i). Therefore, the region of the sea-level line can be attained.

4. CENTROID TRACKING ALGORITHM

In the target imaging of long distance, because the target does not form clear characteristic of the contour and configuration, available information is mostly grey levels and movement characteristic, and so on. The centroid algorithm [12] is appropriate for tracking small target of the sea and sky.

Let S (i, j) be an N × N digital image. Each pixel takes one of L grey levels between 0 and L - 1.

i.e., $0 \le S(i,j) \le L-1$, where $0 \le i,j \le N-1$,

and i is the row coordinate and j the column coordinate of the pixel. Binary image B(i ,j) is obtained after thresholding S(i,j). If the pixel intensity is above a properly chosen threshold, it is declared as a target pixel and the binary image takes '1'.Otherwise it is declared as background pixel and the binary image takes a '0'.

i.e., $$B(i,j) = \begin{cases} 0 & \text{if } S(i,j) \ge threshold \\ 1 & \text{else if } S(i,j) < threshold \end{cases}$$

In case of contrast reversal, the binary image is '1' if S (i, j) is below threshold.

The centroid coordinates (X_b, Y_b) using binary image are given by

$$X_b = \frac{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} iB(i,j)}{\sum_{i=0}^{N}\sum_{j=0}^{N} B(i,j)} , \qquad Y_b = \frac{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} jB(i,j)}{\sum_{i=0}^{N}\sum_{j=0}^{N} B(i,j)} . \qquad (8)$$

5. EXPERIMENTAL RESULTS

In the experiment, we design experimental equipment consisting of DSP image processing board and the high frame and high-resolution digital CCD camera. For the implementation of the above algorithm, we also design the special program for TMS320C6203 DSPs, and the image data from the CCD camera are real-timely processed. Block diagram of small target tracking is given in Fig. 3. Some experimental results are given in Fig. 4.

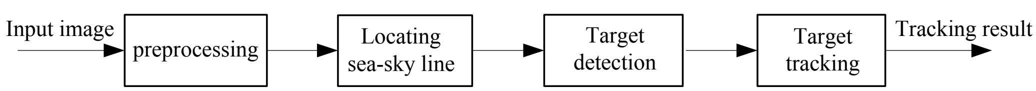
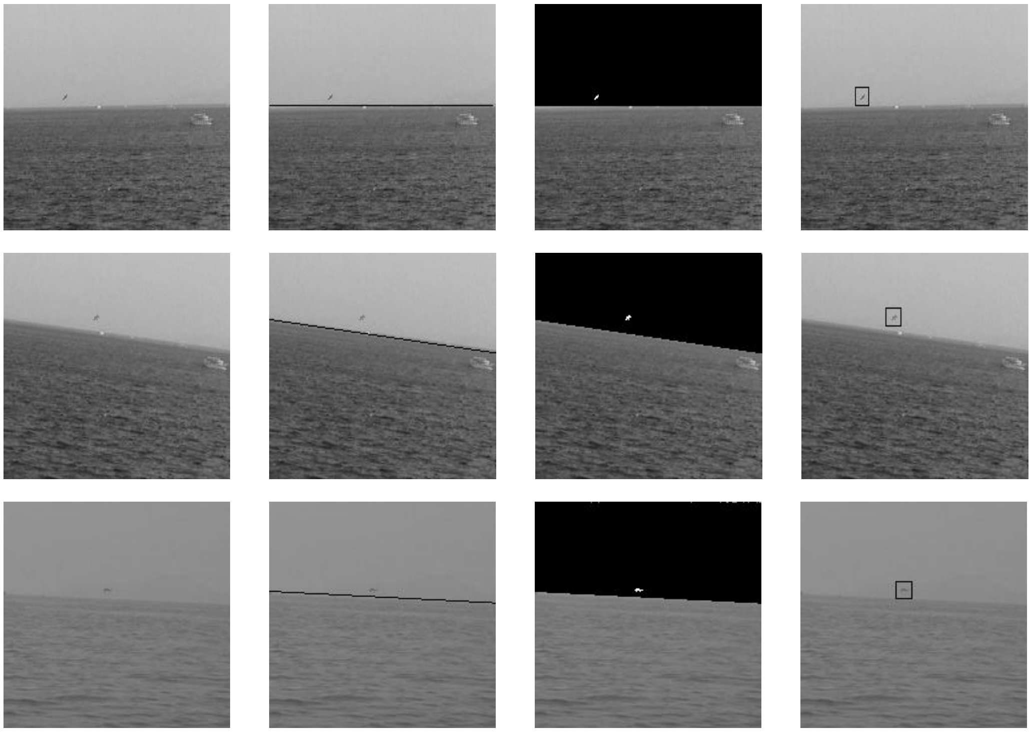


Figure 3. Block diagram of small target tracking under sea-sky background



(a) Original image (b) Results of locating sea-level line (c) Results of target detection (d) Target tracking results

Figure 4. Experimental results of target tracking

6. SUMMARY AND CONCLUSION

In view of the characteristic of low-flying target near the sea, a method of capture and tracking is presented. In accordance with the weather characteristic of the sea, a new algorithm of locating sea-level line is also presented, and it can accurately detect the sea-level line in the case of lower contrast. In this paper, the whole algorithm is very easy to implement, and its structure is greatly simple and calculation time is reduced. Experimental results show that this method can precisely detect and locate low-flying small target in complex background of the sea and sky, effectively eliminate the negative impact of the clutter caused by waves and clouds, and capture and track target real-timely and accurately.

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