Research on Extraction of Ship Target in Complex Sea-sky Background

W J Kang, X M Ding, J W Cui and L Ao

Institute of Ultra-precision Optoelectronic Instrument Engineering, Harbin Institute of Technology, Harbin 150001, China

E-mail: kwjqq@hit.edu.cn

Abstract. Research on the extraction of ship target in complex sea-sky background has important value to improve the capability of imaging-typed sea navigation and nautical traffic control systems. According to the imaging property of complex sea-sky background, a reliable ship target extraction method is proposed in this paper. The general guide line is that getting the sea-sky division line as a priori knowledge and then the target potential area is determined through discontinuous region of the sea-sky division line. Firstly, a local selective window filter is adopted to filter the image; secondly, eight directions Sobel operator edge detection method and gradient Hough transform are combined to extract sea-sky division line in the image; then a multi-histogram matching technique is adopted to remove the sea and sky background and thus ship target is extracted from complex background. The experiments show that our method has the merits of robustness to noise, small computational complexity and stability.

1. Introduction

Through the analysis of ship target image in the sea-sky background under far off orthophoria condition, we get there are three regions: sky region, sea region and sea-sky division line region, as shown in figure 1. So if the ship appears, parts of its area must lie in sea-sky division line region. Thus with the determination of sea-sky division line region, the computational quantity of ship target segmentation can be reduced, at the same time, the irrelevant noise is removed. Reference [1] proposed a row projection histogram to locate the sea-sky division line. This method is only applies to simple background and the binary threshold is difficult to determine. They also proposed another method, which computes the average of row pixels and the maxima of column direction gradient confirming the location. But they can’t consider the slant of the sea-sky division line. What’s more, they failed to care for the disturbance of sea clutter. In reference [2] Z W Zhang improved the idea of computing column gradient in [1] and proposed a Radon line fitting way to extract the sea-sky division line. This method has been succeeded in extract sea-sky division line in ordinary background. But in complex condition the effectiveness is not satisfied. In order to solve this problem, it is important to adopt effective background suppression and target enhancement. To achieve this, in this paper a local selective window filter is adopted to preprocess the image, and then eight directions Sobel operator gradient method and improved Hough transform are combined to extract sea-sky division line in the image, finally a multi-histogram matching technique is proposed to remove the sea and sky background and thus ship target is extracted from complex background.
The rest of this paper is organized as follows. A process designed to smooth image is introduced in section 2. Section 3 discusses how to extract sea-sky division lines based on eight directions Sobel followed by improved Hough Transform. A detailed discussion on multi-histogram matching method will be presented in section 4. In the last section gives some concluding remarks.

2. Background suppression and target enhancement

Because of the complexity of sea-sky background and influence of noise, image sensors introduce large levels of noise and irrelevant details into the image, especially in sea region. Therefore it isn’t usually effectual if we directly proceed to the extraction of sea-sky line. What’s more, simple mean and median convolution filters tend not to produce any significant improvement in image quality. Hence, we propose the use of a 5 by 5 spatially floating window filter to preprocess the image. This filter is a local spatial operator in image space and has been found to reduce noise in the image without significant loss of image detail. The equation is as following:

\[ g(\bar{x}, \bar{y}) = \left\{ \mu_{i} \left| \sigma_{i}^{2} = \min_{j} \sigma_{j}^{2} \right. \right\} \]

Where \( i \) denotes the number of window. We choose 25 5 x 5 windows centered in the current processing pixel and its 4 vertexes along main diagonal and cross diagonal lines. \( f(\bar{x}, \bar{y}) \) is a gray value function of a pixel located in \((\bar{x}, \bar{y})\) in the image, \( g(\bar{x}, \bar{y}) \) is the filtered pixel value, \( \mu_{i} \) and \( \sigma_{i}^{2} \) are the mean and the variance of window \( i \), respectively. Comparing the variances for each neighbored window and the minimum one is determined. Then within the minimum variance window, the filtered pixel value is set to the mean value of the window with the minimum variance. The result is that the filter removes the large amount of details and irrelevant line features, as shown in figure 2. Then the following line extraction algorithm will give a good result.

3. Extraction of sea-sky division line

As we mentioned before, ship target image in the sea-sky background include three regions: sky region, sea region, sea-sky division line region, as shown in figure 1. So if the ship appears, parts of its area must lie in sea-sky division line region. Thus with the determination of sea-sky division line region, the computational quantity of ship target segmentation can be reduced, at the same time, the irrelevant noise is removed. On the basis of classic Sobel operator, we define eight directions Sobel with template increasing to eight to detect edge image, the templates are shown as figure 3. Then edge tracking step is adopt to remove the influence of noise. The connectivity of edge image is detected and
the satisfied pixel is inputted to the improved Gradient Hough Transform to determine the position of sea-sky division line.

3.1. Edge detection
The eight templates convolute with the pixels in image in sequence, then the maximum output’s value and direction are determined as the new value and the direction of that pixel respectively. Generally the sea-sky line is continuous and smooth to a certain extent, whereas noise is stochastic. Considering that in the vicinity of arbitrary point in sea-sky line it can find another point belonging to the line, besides the differences of gray value and direction is impossible big. But the noise doesn’t accord with above-mentioned features because of the randomicity of noise [4]. Generally speaking, utilizing these basic ideas, the actual sea-sky line points can be separated from noise. The procedure is as follows: first selecting a threshold $T$, if the Sobel output is bigger then $T$, the pixel is preliminarily regard as the point in sea-sky line, otherwise noise. But only this simple threshold estimation is not sufficient due to large value of noise. So further determination must be made.

3.2. Hough transform
In general the sea-sky line is not a line but a gradual change strip from bright (sky) to black (sea). Usually this strip is not horizontal but with a slanting direction. In this paper we regard it as a line approximately and use Hough transform method to extract the sea-sky line strip.

Hough Transform (HT) is the classical method of finding the parameters of lines in a binary image [4]. The transform maps a line in an image space $(x, y)$ into a point in the HT parameter space. In polar coordinates, the equation of a line can be expressed as:

$$\rho = x \cos(\theta) + y \sin(\theta) \quad \theta \in \left[0, \pi\right)$$

(4)

Where $(x, y)$ is coordinate of an image pixel, $(\theta, \rho)$ is coordinate of the parameter space. $\rho$ is the distance of the line from the origin and $\theta$ is the angle of the direction normal to the line.

The primary requirement of the transform is a binary edge image as input. In order to reduce the computational complexity due to too many target pixels, a thinning processing is applied to the binary image we have acquired in the last edge tracking step. Then each target pixel in the thinning image maps into a curve in the parameter space domain. Pixels lying on a straight line generate a family of sinusoidal curves that intersect in the same point of the parameter space. To extract the lines, one just needs to find these peaks in the parameter space $(\theta, \rho)$. Then the location of sea-sky division line is confirmed. In this paper, the directions of input points calculating from Sobel are input as $\theta$ parameter, with interval $(\theta-0.4, \theta+0.4)$ radian. Figure 4 illustrates the sea-sky line detected with the proposed Hough transform. There have been other improved Hough Transform methods to detect line feature effectively, limited to the length, in this paper we don’t introduce those method. More details have been discussed in [4] and [5].
4. Multi-histogram matching technique

As mentioned in above, the ship must be lie in the discontinuous region of sky-sea division line, so the search range in image space is constrained in this region enlarged 20 pixels right/left respectively. A multi-histogram matching technique is proposed to delete the sea and sky background. The selective search range is shown as figure 5. Two vertical lines (black) divide the whole region into three parts. The left and right regions are regarded as background, within these parts eight background templates which size is $16 \times 16$ are extracted near the vertical lines as shown in figure 5. The eight selective templates histograms are illustrated in figure 6. We can see from figure 6 that the gray value is concentrated in the sky part (the left four histograms), whereas in sea part the variance is large (the right four histograms). A multi-histogram matching technique based on this analysis is adopted.

As we know the appearance of a region is best described by the distribution of features. Histograms can be used as non-parametric estimators of empirical feature distributions [6]. They reflect luminance statistical distributions. Nagel’s improved likelihood ratio test is adopted to measure the dissimilarity of region’s neighbored gray-level structure. In the following, $D(I,J)$ denotes a dissimilarity measure between the image $I$ and $J$.

$$D(I,J) = \frac{\left[ \sigma(I) + \sigma(J) \right]^2 + \left( \frac{\mu(I) - \mu(J)}{2} \right)^2}{\sigma(I)\sigma(J)}$$

(5)

Where $\mu(I)$, $\mu(J)$ are the empirical means and $\sigma(I)$, $\sigma(J)$ are the standard deviations of the distributions of template and candidate matching region respectively. $D(I,J)$ denotes the dissimilarity degree, when the two comparisons are identical, it reached minimum 1. Above the sea-sky line the candidate background is compared with the top four templates and under the sea-sky line the candidate background is compared with the down four templates. Thus when the dissimilarity degree is smaller

Figure 4. Extraction of sea-sky division line.

Figure 5. The selective reference templates.

Figure 6. Histograms of eight reference squares.
then some threshold, the area belongs to background. In order to improve the reliability of ship target extraction, we fuse the edge information calculated from section 3.1 with this dissimilarity results. Then the ship target can be detected, as shown in figure 7.

![Extraction of ship target.](image)

**Figure 7.** Extraction of ship target.

### 5. Conclusion

In this paper, a thorough ship target extraction method has been presented for complex sky-sea background with great stability. According to the imaging property of ship target in sea-sky background, the goal of ship extraction is converted into the background elimination processing. Considering the ship target must be in the sea-sky line, we propose first to detect the location of the sea-sky division line to reduce the irrelative noise and the complexity of computation. Then there is distribution-based image dissimilarity measures fusing the edge information to detect ship. As seen from the result section, this method can detect ship target in a complex sky-sea background with great stability.

### References

[1] F Zhang, S Q Yang and H C Ni 1991 *Infrared & Laser Technology* **2** 21-25
[2] Z W Zhang, Z G Ma, C Qian and Z C Yu 2005 *Journal of Naval University of Engineering* **17** 97-99
[3] S T Liu, T S Shen, Y L Han and X D Zhou 2003 *LASER & INFRARED* **33** 51-53
[4] Aggarwal N and Karli W C 2000 *Image processing* **3** 873-876
[5] Olmo G. and Magli E. 2001 *Image processing* **3** 338-341
[6] Yossi Rubner, Jan Puzicha, Carlo Tomasi and Joachim M. Buhmann 2001 *Computer Vision and Image Understanding* **84** 25-43