Target Segmentation from Laser Underwater Images Based on Statistic Counteraction *

Fei Peiyan[1], Guo Baolong[1], Zhang Zhengyu[2]
1 *Department of Measurement & Control Engineering, Xidian Univ.*, *Xi'an* 710071
2 *North China Research Institute of Electronic Optics*, *Beijing*, 100015

Abstract The recognition of laser underwater target is a new disquisitive field, in which many problems are open, and segmentation is the key problem. To recognize underwater target, segmentation must be performed efficiently because there is a lot of speckle noise in laser underwater images. According to the principle that noise with identically statistic characteristics can counteract noise in images, a new algorithm called target segmentation from laser underwater image based on statistic counteraction is proposed to remove speckle noise and extract targets with wavelet transform and statistics. Experiments demonstrate that this method is efficient and feasible.

Keywords Underwater target; Statistic counteraction; Laser; Wavelet transform; Morphological filtering
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0 Intruduction

Underwater targets detection by laser is a new and advanced detection technique. It consists of laser technique, communication technique, signal processing and so on. Whether in theory or practical application, it is very important to study and develop this technique. Now, developed countries like America have established their own underwater photoelectric detection systems, and have applied them in civil and military[1]. However, there are some difficult problems in underwater targets detection by laser and we must do something to solve them. One of them is target recognition[2]. Furthermore, it is the key problem for target recognition to make valid segmentation to laser underwater image. To solve this problem, we have studied target segmentation from noisy underwater image.

Segmentation is a key technique to pattern recognition and also the base of extraction characteristic of targets and recognition. When performing segmentation, we can adopt different methods according to different characteristics of objects we deal with, such as recognize object from background in terms of different contemplations[3]. To apply precise segmentation, we know, it is the most important that there must exist outstanding edge between target and background. Hence, when performing segmentation, it is very profitable if we can validly detect boundary between target and background. However, it is not practical for laser underwater target because amount of particulates in seawater seriously reflecting laser backward. And quality of image is unsatisfied although we have used distance selective conduct or synchronous scan technique to overcome backward dispersion. Speckle noise makes the gray level of image change poignantly which decreases ocular quality of images and destroys image details. To carry out valid segmentation, following methods to eliminate speckle noise in images have been used. (1) Lee filtering based on local statistics[4]. (2) Homomorphic filtering based on homomorphic projection[5]. (3) Wavelet soft-thresholding[6,7]. Although these methods can restrain speckle noise, the former two of them make image details destroyed while restraining noise and the loss of images is unfavorable to the subsequent processing. The last one can reserve a certain image details while restraining noise, but its denoised ability is limited to seriously noisy images. In this paper, target segmentation from laser underwater image based on statistic counteraction is proposed to remove speckle noise and extract targets with wavelet transform and statistics in terms of the principle that noise with identically statistic characteristics can counteract noise in images.

1 The Form of Speckle Noise

1.1 The Principle Sketch Map of Laser Underwater Imaging

The block diagram in Fig. 1 shows the principle sketch map of laser underwater imaging. Laser

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Tel:029-88202638 Email:feipeiyan@sina.com
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underwater image is acquired with distance selective conduct. When impulse laser outputs laser, primitive triggering signal is shown and put into multifunction in-out box, then the box puts signal into delay device DG535. Computer makes DG535 output suitable delay triggering signal to ICCD(Intensified CCD) that makes ICCD open and acquire imaging information. Seawater absorbs and disperses laser that arouses attenuation and aberrance of object echo. Moreover, backward light made by seawater dispersion enters ICCD when ICCD is open during experiments. Hence, there exists speckle noise in images.

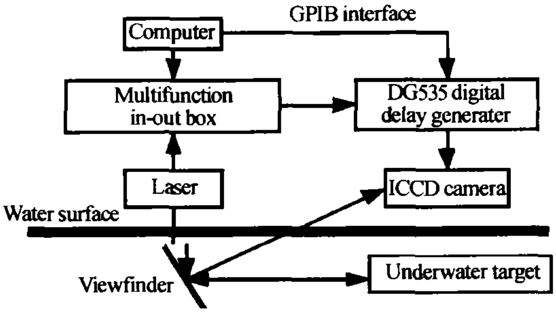

Fig. 1 Block diagram of laser underwater imaging

1.2 The Forming of Speckle Noise

Speckle noise[8] is dispersing echo which is gotten at any point in moderate distance because of light high coherence of signal and coarseness of relative light-wave on object surface during coherency imaging. Dispersing echo consists of many coherency elements and wavelets coming from different surface, moreover, light distance difference of different coherency elements may be several l (l is length of wave) , so coherency wavelets with different phase give birth to interference, which may be strengthen or waken with each other. Finally, grain-shaped intensity image which is called speckle noise is produced.

2 Target Segmentation from Laser Underwater Images Based on Statistic Counteraction

Whether in theory or in practice, underwater target detection and recognition play an important role. However, because of speckle noise existing in laser underwater target imaging, the effect of segmentation is not good if using conventional denoising methods. Since noisy statistic characteristics are similar in underwater images getting under similar conditions, in this paper, for image denoising and enhancement, noise characteristic is extracted with no target noisy images to counteract noise in target images in terms of the principle that noise with identically statistics characteristics can counteract with each other. According to this theory, we apply noise counteraction to noisy images based on enhancing images with wavelet. Here, we suppose that statistic characteristics of noise in laser underwater images are similar. The flowchart of statistic counteraction is as follows.

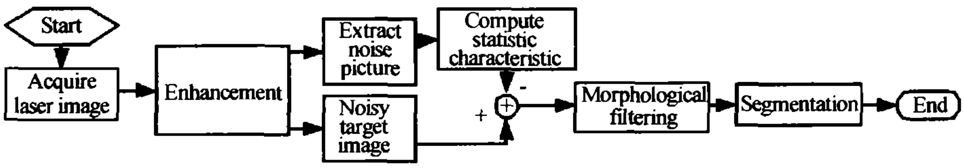

Fig. 2 Flowchart of Target Segmentation from Laser underwater Image Based on Statistic Counteraction

2.1 Image Enhancement

Since wavelet representation has characteristic of time-frequency locality, it has been widely used in signal processing, image processing, CT imaging, radar etc..

In this paper, we use wavelet transform to enhance noisy images in order to enhance what we concern in images while restraining noise. In practical processing, we use underwater image A and non-object image B(namely, background image) at same distance to finish image enhancement with wavelet analysis. The concrete process is as follows.

1) Get underwater image F and background image G;

2) Apply wavelet analysis at the resolution 2^{-1} respectively, getting F_{LL}, F_{LH}, F_{HL}, F_{HH}, G_{LL}, G_{LH}, G_{HL} and G_{HH}, where F_{LL} and G_{LL} are image approximations, F_{LH}, F_{HL}, F_{HH}, G_{LH}, G_{HL} and G_{HH} image details respectively.

3) Get F_{LL} and G_{LL}, compute absolute differences DF_{LL} of them.

4) Zoom out DF_{LL} for 4 times to prepare for successive processing, marking A. There are many methods to magnify images. Here, we adopt bilinear interpolation.

To decrease noise, we abnegate F_{LH}, F_{HL}, F_{HH}, G_{LH}, G_{HL} and G_{HH}, which contain amount of details, and quite amount of information of speckle noise distributes in them. Moreover, most information, which our eyes are sensitive to, concentrates in approximations F_{LL} and G_{LL} where image representation enables important information more outstanding. The block diagram we adopt to enhance images is as follows.

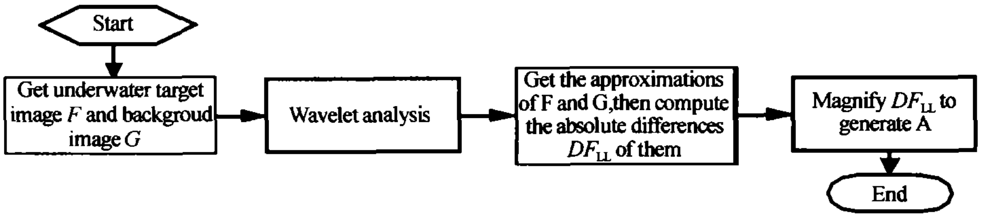

Fig. 3 Block diagram of image enhancement

2.2 Statistic Counteraction Method

There are many statistics in statistic analysis, such as autocorrelation, covariance, standard deviation, mean, deviation and so on. According to requirement of image segmentation, we use mean and deviation in this paper. The mathematic expressions are as follows.

$$\text{Mean}: \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$$\text{Deviation}: s = \left(\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2\right)^{1/2}$$

where x_i is value of pixel, n is the total number of pixels. Here, deviation is used to compare similarity of images. The smaller deviation is, the more similar images are.

The steps of statistic counteraction are as follows:

1) Get underwater image A which has been enhanced with wavelet analysis.

2) Acquire a certain size of background in image A, then magnify it as the same size of image A with bilinear interpolation, which is called background image B.

3) Split images A and B into identical image blocks respectively.

4) Calculate means $A\bar{x}_j$, $B\bar{x}_j$ and deviations As_j, Bs_j of image blocks, $j = 1, 2, \cdots J$, J is the total number of image blocks;

5) Calculate minimum minAm of means $A\bar{x}_j$ and minimum minBm of means $B\bar{x}_j$, then get absolute value D of them.

6) If minAm is bigger than minBm, then $B\bar{x}_j + D = B\bar{x}_j$, $B + D = B$, else $A\bar{x}_j + D = A\bar{x}_j$, $A + D = A$.

7) Calculate means A_x, A_s, B_s, $B\,x$ of $A\bar{x}_j$, $B\bar{x}_j$, As_j and Bs_j and maximum maxBs of Bs_j.

8) If (maxB_s − B_s) is bigger than ($A\bar{x}_j - A_x$), then set the values of $A\bar{x}_j$ 0, else the values of $A\bar{x}_j$ invariable.

9) Perform morphological filtering and output the result.

The flowchart of statistic counteraction processing is shown in Fig. 4.

From steps (6) and (8) we know that the algorithm has the property of adaptability. Since max B_s, B_s, $A\bar{x}_j$, A_x, minAm and minBm vary with processed images, when images changed, their values are changed correspondingly.

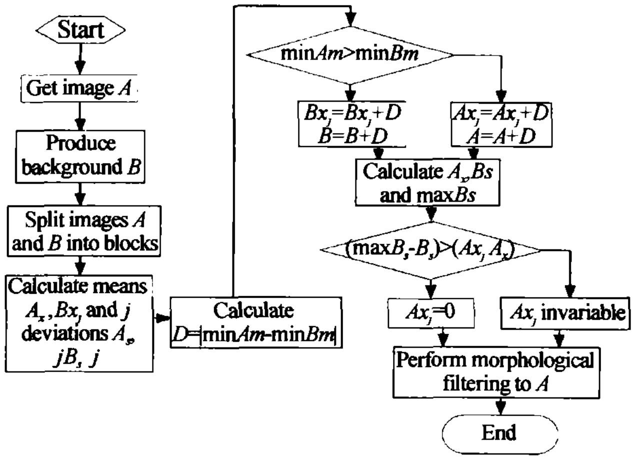

Fig. 4 The flowchart of statistic counteraction processing

Because blocks processing is adopted in the algorithm, some disperse and irregularly tactic image blocks appear in images processed by statistic counteraction. To eliminate the effect caused by the blocks, we perform post processing using morphological filter. The structure elements we used are as follows.

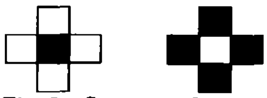

Fig. 5 Structure elements

3 Experimental results and analysis

The image of trigonal iron board under water is shown in Fig. 6. Illumination is blue-green laser. From this image, we see that the object almost submerged in background noise. It is hard to extract the object if we directly use conventional methods to filter noise. Furthermore, it is difficult to extract object with information of edges from Fig. 6. The enhanced image of Fig. 6 with wavelet analysis is shown in Fig. 7, from which we known that speckle noise is enhanced while the object is enhanced. In Fig. 8, the object is extracted with statistic counteraction, where Fig. 8 (a)

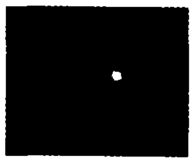

Fig. 6 Image of underwater object

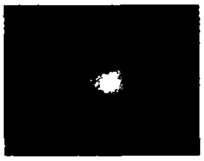

Fig. 7 Enhanced image

(a)Blocks 4×4 (b)Blocks 8×8

Fig. 8 Results with statistic counteraction

is the result with blocks 4×4, Fig. 8(b) is the result with blocks 8×8.

From the results of experiments, two conclusions can be gotten, (1) To extract target precisely, the size of image blocks cannot be too large. (2) Speckle noise of laser underwater image can be filtered effectively. Since laser has good unilateralism, a brighter facula appears in images when laser encounters obstacles with larger density than water. Moreover, a bright facula indicates that larger objects exist in the domain where laser is projected.

According to experiments, we've learned about that we can get better segmentation with statistic counteraction processing laser underwater images with speckle noise. Furthermore, our experiments prove that this method is efficient to determine whether there have objects in images or not.

Fig. 9 Underwater image without object

Fig. 10 Enhanced image

Fig. 11 Result with statistic counteraction

4 Conclusion

In this paper, we proposed an algorithm of target segmentation from laser underwater image based on statistic counteraction. Experiments have proved that it is efficient and feasible. Its concrete characteristics are as follows.

1) It is effective to eliminate speckle noise which interferes with extracting object and segment objects in images.

2) The thresholding of statistic counteraction has adaptability. See it in Section 2.2.

3) Through experiments, we prove that a singular color image appears if there is no object in images.

Comparing with one-dimensional signal, two-dimensional signal (image) is more frank and straight. We think that underwater target recognition using image will boost rapidly.

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水下激光目标的统计对消分割法

费佩燕[1] 郭宝龙[1] 章正宇[2]
(1 西安电子科技大学,测控工程系,西安 710071)
(2 华北光电技术研究所,北京 100015)
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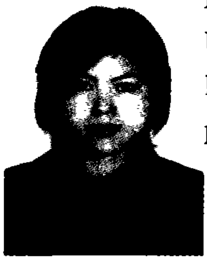
摘 要 水下激光目标的识别是一个崭新的研究领域,有许多问题需要解决,其中,目标分割是关键. 水下激光图像中夹杂着严重的散斑噪声,受其影响,要识别水下激光目标,就要对图像进行有效的消噪,然后进行目标分割. 本文依据具有相似统计特征的噪声可抵消图像中的相应噪声这一基理,结合小波变换和统计法,提出了一种水下激光目标的统计对消分割法,以去除噪声,提取目标. 实验结果表明该方法是有效可行的.
关键词 水下目标;统计对消;激光;小波变换;形态滤波



Fei Peiyan was born in Shanxi, China. She received B. S. and M. S. degrees from Xi'an University of Engineering Science & Technology in 1997 and 2001, respectively. She became a Ph. D. candidate in circuit and system at Xidian University in Sep, 2001. Her current interest is image processing and pattern recognition.