

Real-Time Underwater Target Classification Method for Multi-resolution imaging Sonar of the AUV

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Abstract—How to accurately and fast classification obstacle is the key of real-time obstacle avoidance and avoidance decision for autonomous underwater vehicle. According to the characteristics of the multi-resolution imaging sonar, we extracted the obstacle information and characteristics from sonar image, and the AUV can quickly make decision with underwater obstacles classification. Finally, the data of lake test verified that the method of real-time image processing and underwater target classification is feasible and effective.

Keywords—multi-resolution imaging sonar; autonomous underwater vehicle; sonar image processing; target classification;

I. INTRODUCTION

When the autonomous underwater vehicle (AUV) is an intelligent robot that can execute all kinds of missions in the complicated environment, it maybe encounter the obstacle which is uncharted such as: reefs, oil drilling platform, uncharted island and so on during the voyage. Obstacle avoidance means that an AUV can autonomously sense unknown obstacle and adjust its trajectory to avoid collision in real time. Therefore, AUV needs the ability of acquiring information of barrier and obstacle avoidance. As an effective means of detection, multi-beam imaging sonar has played a central role for the AUV. In practice, the multi-beam imaging sonar seems to be the AUV's eye. It is the base of AUV to make real-time obstacle avoidance decision and complete the mission, and the image processing and obstacle classification method is the soul of AUV avoidance decision and mission.

In recent years, the applications of multi-beam imaging sonar are more and more widely in the field of ocean by the development of sonar technology. The decision-making of collision avoidance and avoidance decision have become an important research direction in the field of underwater robots. Sonar image processing is the base of the collision avoidance and target classification. Sonar image processing includes image filtering, image enhancement, fuzzy clustering and morphological methods. But the sonar image relative to the optical image has the characteristics of low image resolution, noise interference, multi-path phenomenon, Doppler effect, etc [1]. Zhao Chunhui, Shang Zhengguo et al. proposed multi-resolution domain HMT image denoise and enhancement algorithm which based on Hidden Markov model and verified by experiments to obtain higher signal-to-noise ratio [2]. David W. Krout and William Kooiman presented the image

processing algorithms as well as the tracking algorithms used to take the imaging sonar data and track a non-stationary underwater extended object [3]. Shi Zhao described a fuzzy logical algorithm used in the detection of underwater obstacles in natural shallow water environment [4]. Ken Too and Kai Wei Bong proposed a successful system of obstacle detection, avoidance and anti-collision for AUV [5]. Shi Zhao and Tien-Fu Lu presented an innovative method for the detection of underwater object [6]. Ai Ling Chew and Poh Bee Tong did some research of detection and classification of man-made target in sonar images [7]. Yvan Petillot and Ioseba Tena Ruiz presented a new framework for segmentation of sonar images, tracking of underwater objects and motion estimation [8].

The paper tried to solve the problem that how to rely on the multi-resolution imaging sonar of the AUV to fast and accurately distinguish the obstacle and classify the obstacle in real-time in complicated sea environment.

II. MULTI-RESOLUTION IMAGING SONAR

This article uses the Blueview P450-130-D image sonar was produced by the United States, and it is very suitable as obstacle avoidance sonar of AUV with the advantages of low price, small size, and low power consumption. The following is the main performance index: The frequency of 450KHz, horizontal angle of 130°, vertical angle of 10°, a maximum range of 250m, the number of beams is 768, beam spacing of 0.18°, resolution of 5cm. Blueview multi-beam imaging sonar is shown in figure 1.



Fig. 1. Blueview multi-beam imaging sonar

III. SONAR IMAGE PROCESSING

Image processing is an important part of the target classification, which needs according to the requirement of sonar image features. In this paper, the image processing process is shown in figure 2.

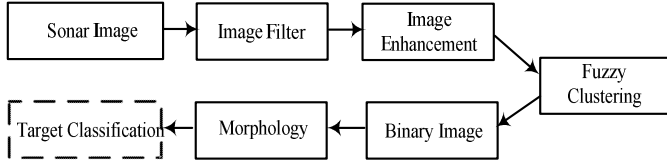


Fig. 2. The process of image processing

A. Image filtering and enhancement

The noise of sonar image is random disturbance, and it can be formed the Gauss noise, salt noise, pepper noise and the speckle noise with the difference in transducer sensitivity, temperature fluctuations, the marine environment, multipath interference[9]. Multi-beam imaging sonar is very sensitive to the noise, so filtering and enhancement process must be carried out after the target classification.

We acquired the original sonar image data from AUV by the lake test. So we selected two consecutive frames of sonar original images which are shown in Figure.3, when the AUV avoided the right front obstacle in the lake. It can be seen clearly the underwater obstacle around lots of random noise and acoustics disturbance in the original sonar image. In this paper, image filtering and image enhancement method based on the software development kit of the image sonar, and we set the threshold by dynamic maximum and minimum value of the sonar image.

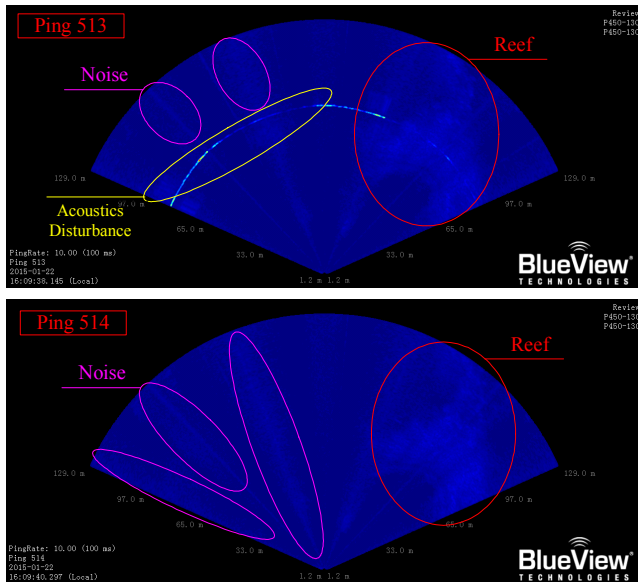


Fig. 3. The original sonar images

In the case of the 513 ping, the result of image filtering and image enhancement is shown in Figure.4. The result shows that a lot of noise and speckle noise is removed and the signal-to-noise ratio is greatly improved and the contour information of target has also been enhanced.

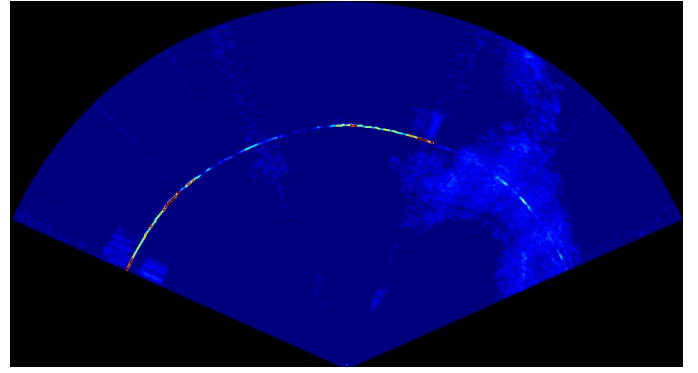


Fig. 4. The result of the filtering and enhancement method

B. Fuzzy clustering and morphological algorithm

Image segmentation is a technique and process with similar pixel of image to be classified and extracted [10]. In this paper we adopted K-means clustering method to deal with the sonar image, which based on the traditional fuzzy C-means algorithm. Firstly, an accurate number of K was determined as the initial cluster center. Then we assigned the remaining objects to the nearest class according to the distance form the center. And a new cluster center was formed by recalculating each class object. This process was repeated again and again until each cluster center was convergent. The K-means clustering algorithm is more suitable in the complicated marine environment.

Morphology is a nonlinear filtering method; erosion and dilation are the basis of morphology. Erosion can eliminate boundary points and filter out the noise that is small and meaningless pixels. After the data of the erosion treatment, image can filter out most of the noise, but also corroded the boundary of the valid data. So it must carry out the dilation treatment [11], after the erosion treatment. Dilation can smooth the outline of the image and fill the gap on the contour. In this paper, we adopted the erosion treatment before the dilation treatment. This treatment can remove the bright spot, clear image edge burr and isolated points and fill the holes in the image, while it can retain the large target area.

The result of K-median fuzzy clustering and morphology method is shown in Figure 5. The result proved that the noise basically was removed, and the useful data was recovered out.



Fig. 5. The result of K-median fuzzy clustering and morphology algorithm

IV. UNDERWATER TARGET CLASSIFICATION

Sonar image processing is the basis of sonar image classification. Though a lot of noise is removed after image processing, there are still a lot of random interference and speckle noise hard to remove. So we adopted underwater targets classification method to remove the random interference and speckle noise.

In this paper, we mainly study the target classification method with the static obstacle, and we reference sonar image processing results to extract the appropriate obstacle target features (including target's edge, gray feature, area feature, shape feature, etc.). And this paper takes into account the correlation of adjacent frame. Finally, the target classification method can remove all random interference and speckle noise, which can supply the real-time obstacle information for AUV.

The feature extraction is the key of the entire underwater target classification system. This paper analyzes the characteristics of the sonar image underwater obstacle, selecting the classic shape features extraction method which is more applicable to classification underwater obstacle images. Firstly, extracting the image of underwater obstacle edge line using Watershed technique and mathematical morphology method, and then a clear curve of the barrier edge has been got which is shown in figure 6.



Fig. 6. The barrier edge

For the underwater obstacle, the geometrical features are the first features, which are the basic features. The geometric features that include the length of shaft, eccentricity, area, perimeter, geometry center can be extracted as the parameters of underwater obstacle, which is shown in figure 7.

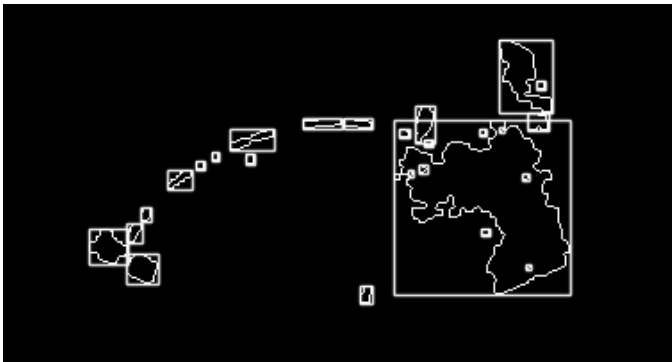


Fig. 7. The images after feature extraction

Then, we judged obstacle on the target features (including target's size, area feature, shape feature, etc.) and correlation of adjacent frame whether the obstacle is real obstacle. Finally, we classify the underwater barrier image and remove the random interference and speckle noise, which is shown in figure 8. By the classification method, the avoidance decision program of AUV will easily choose how to avoid obstacles.

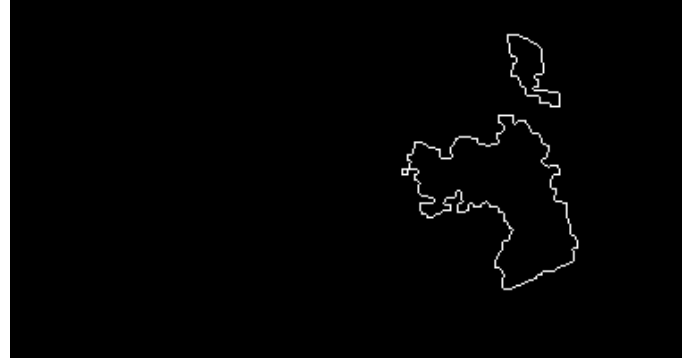


Fig. 8. The result of the target classification method

V. CONCLUSION

This paper proposes a real-time image processing and the target classification methods which apply to the high resolution multi-beam image sonar of AUV. The target classification method is also integrated with correlation of adjacent frame, so it has good robustness. This method can improve the accuracy of the target classification, and has a good real-time performance. And the methods are proved to be feasible and effective by the lake test data. Finally, the methods of this paper can ensure the safety of the AUV in the water. And the research results could be the important foundation for the development of the obstacle avoidance and avoidance decision for underwater vehicles.

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