3P6-5

Proceedings of Symposium on Ultrasonic Electronics, Vol. 36 (2015)
5-7 November, 2015

A configuration-conjunct threshold segmentation method of underwater linear object detection for forward-looking sonar

Lixin Liu[12†], Hongyu Bian[1], Shin-ichi Yagi[2], and Xiaodong Yang [3] ([1]Sci. and Tech. on Underwater Acoustic Lab., Harbin Eng. Univ., Harbin, China; [2]Grad. Sch. of Inf. Sci., Meisei Univ., Tokyo, Japan; [3]Collaborative Research Center, Meisei Univ., Tokyo, Japan)

1. Introduction

Underwater operation, such as objects detection, obstacle avoidance, and target tracking[1)], using forward-looking sonar have been widely applied because of the relative high frame rate and resolution. Image segmentation, as a basis of automatic visual understanding, contributes to underwater linear object detection such as suspending tubes, sustaining pipes, petroleum ducts, as well as parts of autonomous underwater vehicles, and so on.

However, grating-lobe and multi-path[2)] disturb sonar imaging, and they might cause over-segmentation easily because conventional threshold segmentation methods search the segmentation threshold mainly based on gray level distribution without considering the structural prior probability. In another word, the grating-lobe and multi-path disturbance that with high similarity with the true object, are quite difficult to get rid of by de-noising methods and they intrude the gray level distribution which result in fuzziness in sonar images understanding.

To seek for a more robust segmentation method and verify if it is possible to guide the segmentation threshold evolvement of forward-looking sonar images using configuration prior probability, a configuration-conjunct threshold segmentation method of underwater linear object detection is discussed. A series of segmentation experiments are implemented. Experimental results are compared, including the segmentation output and computational cost using different methods, which demonstrate the effectiveness of the proposed method.

2. Methods

Figure 1 shows the processing flow of the proposed method. Assume that τ_k is the threshold at time k, and $\Delta\tau$ is the step size. As the beginning of segmentation, the initial threshold is calculated by conventional Otsu segmentation method.

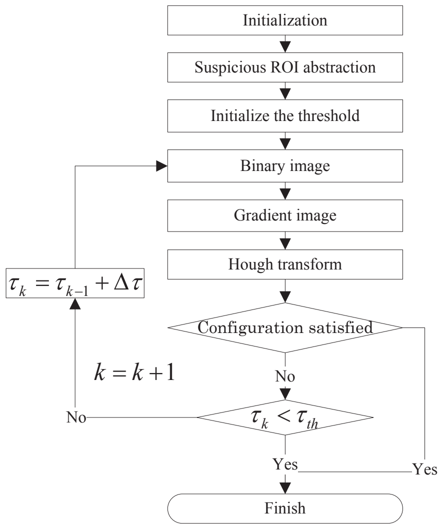


Fig. 1 Schematic diagram

Linear relation is detected by Hough transform from edged image, among which a pair of peaks is chosen in the transformed space. The coordinate interchange of Hough transform is shown in **Fig. 2**. The ubiety of the two correlating lines in image domain, including the slope correlation of the two lines and the distance between the two lines and the most suspicious area, is judged to supervise the threshold evolvement. The evolved threshold is implied in segmentation for the next judgment. The evolvement stops when the ubiety of the two detected lines satisfied the terminating condition.

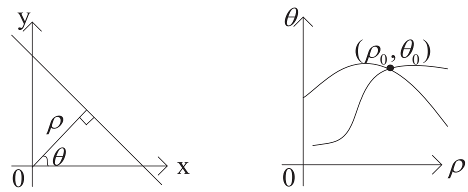


Fig. 2 Hough transform

3. Experimental results

1. Setup

Experiments are implemented on sonar images of an underwater suspending pipe, which are taken using DIDSON forward-looking sonar in a reverberation tank, as shown in **Fig. 3**. The

----

13xy051@stu.meisei-u.ac.jp

rotation motor rotates 180 degrees with an interruption per 5 degrees, and 37 frames that taken at the interruption are used for segmentation.

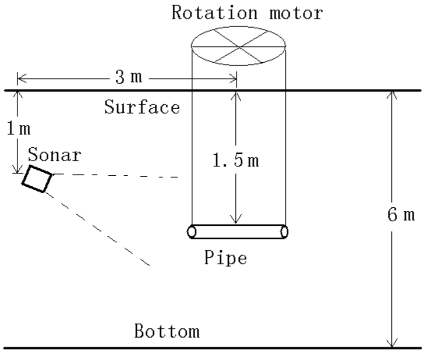
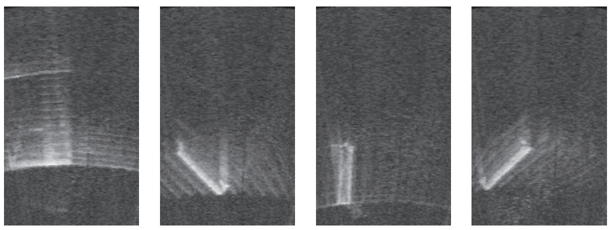


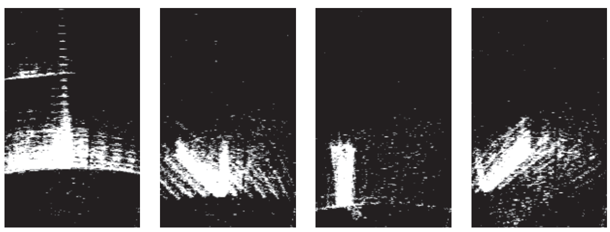
Fig. 3 Experiment setup

2. Segmentation results

Figure 4 shows the original gray images and segmented binary images of conventional Otsu method and the proposed method. Otsu segmentation result in serious over-segmentation but the proposed method can effectively extract linear objects with neat and obvious edges.



(a)



(b)

(c)

Fig. 4 Segmentation results (from the left to the right: 0 degree, 45 degrees, 90 degrees, and 135 degrees): (a) original sonar images; (b) Otsu; (c) the proposed method.

Statistical data of Otsu, local Otsu, property histogram, level-set-based, MRF-based, and the proposed method is shown in **Fig. 5** respectively. The mean effective area of the MRF-based method and the proposed method are very close and they are both smaller than the ones of other methods. However, the variance of the proposed method is smaller than any other method which means it is the most stable method among them.

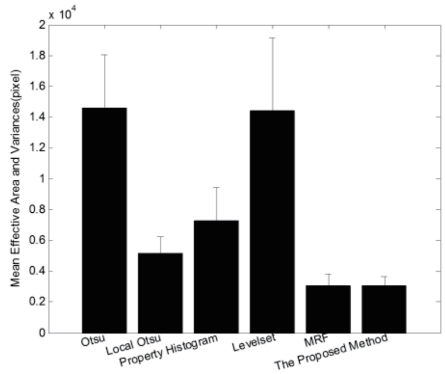


Fig. 5 Effectiveness compare

3. Computational cost

Table I Computational cost

Method	Computational time (s)
Otsu	0.0014
Local Otsu	0.099
Property Otsu	0.002
Level-set	24.4
MRF	3852
Our method	0.371

Computational time of the proposed method is also compared with conventional segmentation methods and is shown in **Table I**.

4. Conclusions

A configuration-conjunct threshold segmentation method is implemented in forward-looking sonar images with high greeting-lobe and multi-path disturbance. Experimental results show that the proposed segmentation method can keep good tradeoff between segmentation precision and computational cost. The proposed method redounds to further process for unsupervised underwater visual understanding.

Acknowledgment

This paper is funded by the China Scholarship Council and the National Natural Science Foundation of China (Grant No. 41376102).

References

1. L. Liu, H. Bian, and G. Shao: IEEE IMCCC. 2012, p. 985.
2. L. Liu, H. Bian, and G. Shao: IWMST. 2012, p. 111.