AN ACOUSTIC-ALIASING-RESISTANT TRACKING METHOD FOR FORWARD-LOOKING SONAR

Lixin Liu[a], Hongyu Bian[b], Wen Xu[a]

[a]Institute of Deep-sea Science and Engineering, Chinese Academy of Sciences, Sanya, 572000, China
[b]Underwater Acoustic Laboratory, Harbin Engineering University, Harbin, 150001, China

Lixin Liu, Institute of Deep-sea Science and Engineering, Chinese Academy of Sciences, Sanya, 572000, China, +86-898-88386143, liulixin512@163.com

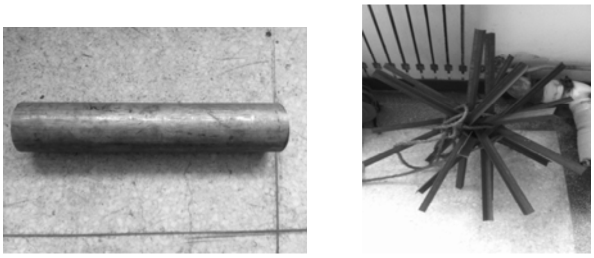
Abstract: *Taking a forward-looking sonar as the spatial center, it lacks the recognition capability for different objects that at the same range and the same horizontal angle, but different vertical angle. When the target moves toward the spatial location that satisfied the conditions mentioned above, the echoes of the target and the obstacle are overlapped, which causes the acoustic aliasing phenomenon. This study focuses on underwater moving target tracking using forward-looking sonar image sequences. In the aspect of target contour iteration between frames, the strategy of controlling the inner particles using the shape prior, and the feasibility of mapping the distance between particles and the shape prior to particles weight are discussed. The moving information of the interested target and the energy flow are used to judge the happening and disappearing of the acoustic aliasing. The tracking models are dynamically changed, so as to estimate the moving status of the underwater target. Experiments of looking forward situation are designed and tested, and the results show that compare with conventional methods, the proposed method can deal with acoustic aliasing felicitously and it has robustness in simple obstacle or simple underwater background. This study contributes to improving the intellectualization of underwater robot vision.*

Keywords: *image tracking, acoustic-aliasing, forward-looking sonar, contour iteration*

1. INTRODUCTION

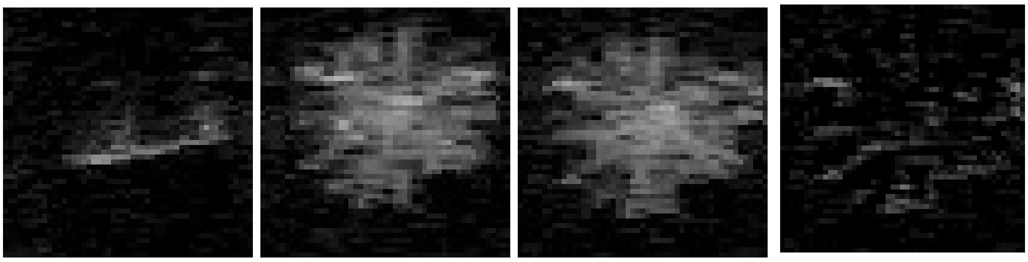
Objects are easily occluded in the underwater environment. When the target moves toward an obstacle, and the spatial relation between the target and the obstacle satisfies a certain location situation to the observing forward-looking sonar, the echoes from the target and the obstacle are overlapped. This happens a lot in underwater environment, and what happens most is that the target and the obstacle are at the same range and the same horizontal angle, but different vertical angle to the sonar.

To supervise the trajectory of underwater targets, intelligent vision processing of the forward-looking sonar is necessary [1]. However, satisfied sonar images cannot be easily obtained [2, 3]. When occlusion happens, it is more difficult to distinguish the target from the obstacle [4]. The spatial relation of object and the obstacle satisfies the situation mentioned above, and the imaging result is shown in Fig. 2(c). As shown in Fig. 1-2, no obvious differences can be seen in Fig. 2(b) and Fig. 2(c), and the difference image Fig. 2(d) does not equal to the difference between Fig. 2(c) and Fig. 2(a). Centricity is not enough to describe target when echo signal was submerged or weakened.



(a) (b)

Fig. 1 Photos of the object and the obstacle (a) the object; (b) the obstacle



(a) (b) (c) (d)

Fig. 2 Sonar images: (a) the target, (b) the occlude, (c) the target is invisible, (d) the difference of (c) and (b)

The contour describer [5] contributes to maintain the estimation to the current state [6-12]. Contour tracking [13-16] utilizes contour describer with [13, 15, 16] or without [14] association with filtering technique. Level set function [17-22], which was introduced into computer vision firstly by Malladi et al. [17] is an effective method of obtaining contour describer. Level set method is able to represent contours against topological changes using iterations in image domain [18]. Maria Lianantonakis actualized sidescan sonar image segmentation using level set function [19]. Four-phase piecewise constant model was used by Wang [20] to extract contours of object-highlight and shadow regions but with high computation cost. Li proposed LBF (Local Binary Fitting) energy model [21] in 2007, which localized Chan-Vese model [5, 22] by LBF energy with a kernel function. As further research of LBF, a strict local binary fitting energy was used to segment sonar images selectively by changing the initial contour [23].

2. METHODS

In the proposed method, the Euclidean distance between targets is calculated and used to occlusion detection and occlusion accomplished detection when target is going into and going out of the occlusion area respectively. The proposed method maintains target statement estimate and transmit the tracking model by modeling the occlusion area. A new model for the obstacle will be automatically created when occlusion happened, and the tracking target turns to be the obstacle.

At the same time, the created new model will be joined to the joint model, but the statement transition keeps the same. Tracking target turns to be the prior one after the occlusion factor judging that the occlusion is accomplished, and the unnecessary model will be ignored.

In a word, the moving information of the interested target and the energy flow are used to judge the happening and disappearing of the acoustic aliasing. The tracking models are dynamically changed, so as to estimate the moving status of the underwater target.

3. EXPERIMENTS AND ANALYSIS

Experiments of looking forward situation are designed, as shown in Fig. 3. The feasibility of constraining contour tracking using level set evolution between temporal adjacent frames is validated by real sonar images taken by a dual-frequency identification sonar (DIDSON), which is placed 2 meter under the water surface in a reverberation tank. Target and its sonar image are shown in Fig. 1(a) and Fig. 2(a).

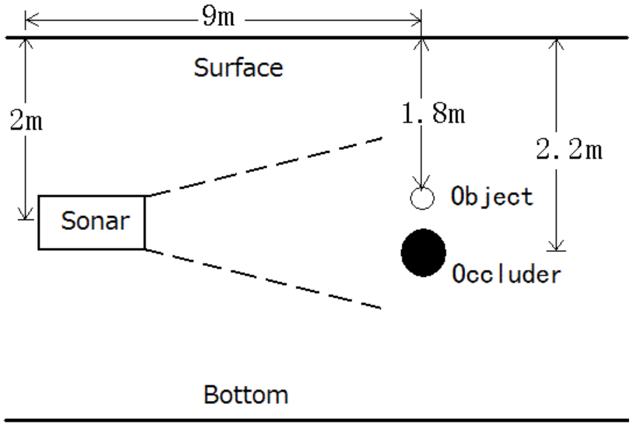


Fig. 3 Experiment setup

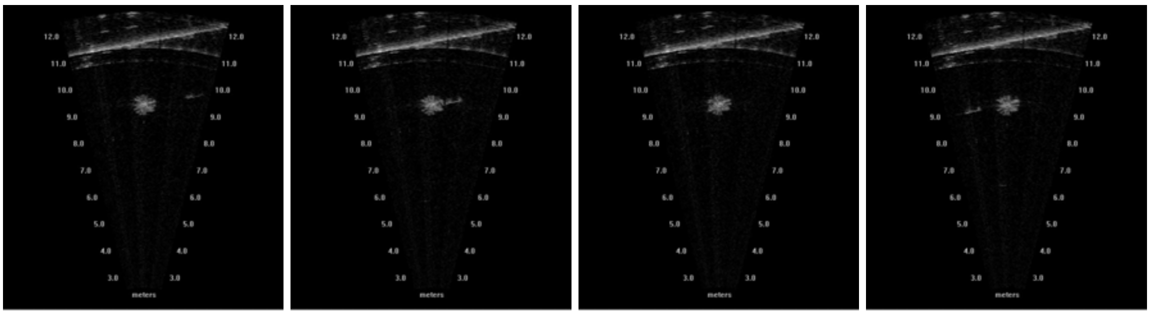
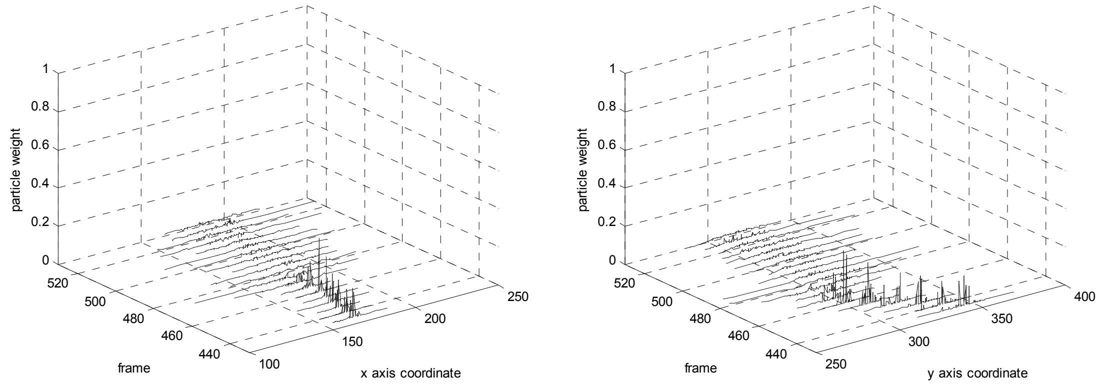


Fig. 4 Original images (from the left to the right: the 431st, 460th, 490th, and 520th frame)

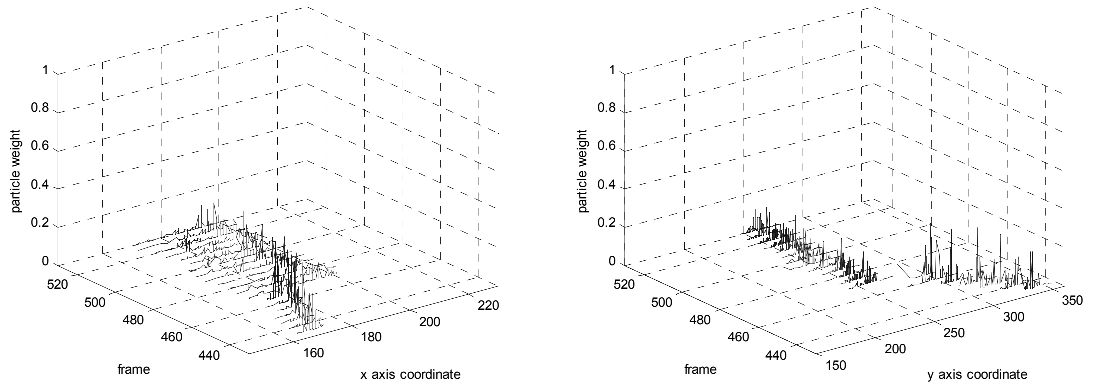
The imaging results are shown in Fig. 4. The obstacle is hung 9 m in front of the sonar in the tank, with a fixed depth of 2.2 m. The target is hung 1.8m under the water surface and moves in a line in front of the sonar from 10 m to 9 m.

Two conventional methods are compared with the proposed method, namely particle filtering (PF), and GATE. The change of particle weight along with frames of PF, GATE, and the proposed method are shown in Fig. 5, Fig. 6 and Fig.7 respectively.



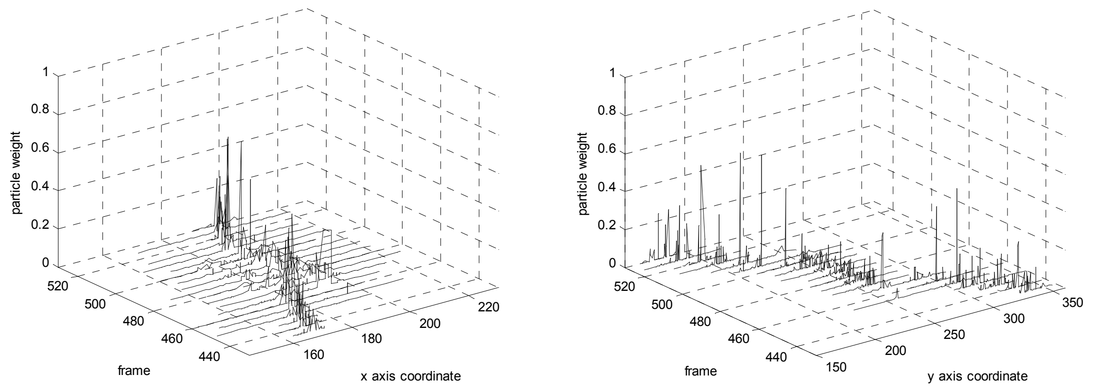
(a) *(b)*

Fig. 5 Particle weight change of PF: (a) x axis, (b) y axis



(a) *(b)*

Fig. 6 Particle weight change of GATE: (a) x axis, (b) y axis



(a) *(b)*

Fig. 7 Particle weight change of the proposed method: (a) x axis, (b) y axis

4. CONCLUSION

Experiments results show that compare with conventional methods, the proposed method can deal with acoustic aliasing felicitously and it has robustness in simple obstacle or simple underwater background. This study contributes to improving the intellectualization of underwater robot vision.

5. ACKNOWLEDGEMENTS

This paper is sponsored by the Innovation Foundation of Chinese Academy of Sciences (Grant No. CXJJ-17-M126), the Natural Science Foundation of Hainan Province (Grant No. 417211), and the Strategic Priority Research Program of the Chinese Academy of Sciences (Grant No. XDA13030102).

REFERENCES

[1] **Lei Fei**, **Zhang Xinying**, Underwater target tracking based on particle filter, 7th International Conference on Computer Science & Education, Melbourne, VIC, pp.36–40, 2012.

[2] **Lixin Liu**, **Hongyu Bian**, **Shin-ichi Yagi**, and **Xiaodong Yang**, A prior-knowledge-based threshold segmentation method of forward-looking sonar images for underwater linear object detection, *Japanese Journal of Applied Physics*, 55(7S1), pp. 07KG06-1-07KG06-7, 2016.

[3] **Michaels Asard**, **Andrew Blake**, CONDENSATION — Conditional Density Propagation for Visual Tracking, International Journal of Computer Vision, 29(1), pp.5-28, 1998.

[4] **Daniel E. Clark**, **Kusha Panta**, **Ba-ngu Vo**, The GM-PHD filter multiple target tracker, International conference on information fusion, Florence, pp.1-8, 2006.

[5] **L. Vese**, **T. Chan**, A Multiphase Level Set Framework for Image Segmentation Using the Mumford and Shah Model, International Journal of Computer Vision，50(3), pp.271-293, 2002.

[6] **Lv N**, **Feng Z R**, Nonlinear interacting particle filter algorithm, Control and Decision, 22, pp. 378-383, 2007.

[7] **Wang T. T.**, **Guo S. Q.**, Overview of particle filter algorithm, Instrumentation Technology, pp. 64-66, 2009.

[8] **Gong Yisong**, **Gui Qingming**, **Sun Fuping**, Survey and Prospect of the Fusion of Intelligent Computational Approaches and Particle Filtering Technique, Hydrographic Surveying and Charting, pp. 74-76, 2009.

[9] **Liu Lixin**, **Bian Hongyu**, **Shao Guofeng**, An Improved PF for Underwater Target Tracking of Forward-looking Sonar, The International Workshop on Modern Science and Technology, Tokyo，Japan，pp.111-115, 2012.

[10] **Liu Lixin**, **Yagi Shin-ichi**, **Bian Hongyu,** Motion Compensated Speckle Tracking via Particle Filtering, Japanese Journal of Applied Physic, 54(7S1), pp.07HF17, 2015.

[11] **Fang Zheng**, **Tong Guofeng**, **Xu Xinhe**, A localization method for particle-filter based on the optimization of particle swarm, Control Theory and Applications, 25(3), pp. 533-535, 2008.

[12] **Liu Lixin**, **Bian Hongyu**, Underwater Visual Tracking for AUV Based on PSOPF, International Conference on Instrumentation & Measurement, Computer, Communication and Control, Harbin，China, pp.973-977, 2012.
[13] **Zha Yufei**, **Zhang Yu**, **Bi Duyan**, Moving Objects Tracking Using Region –based Active Contours, Journal of Image and Graphics, 11 (12), pp.1844-1848, 2006.
[14] **Cheng Luo**, **Xiongcai Cai**, **Jian Zhang**, GATE: A Novel Robust Object Tracking Method Using the Particle Filtering and Level Set Method, Digital Image Computing, pp.378-382, 2008.
[15] **Thomas Brox**, **Mikael Rousson**, **Rachid Deriche**, **Joachim Weickert**, Colour, texture, and motion in level set based segmentation and tracking, Image and Vision Computing, 28, pp.376-390, 2010.
[16] **Xianfeng Fei**, **Koichi Hashimoto**, An Object-Tracking Algorithm Based on PF with Region-Based Level Set Method, IEEE International Conference on Intelligent Robots and Systems, Taiwan, pp.2908-2913, 2010.
[17] **R. Malladi**, **J. A. Sethian**, and **B.C.Vemuri**, Shape modeling with front propagation: A level set approach, IEEE Trans, Pattern. Anal. Mach. Intell., vol.17, no.2, pp.158-175, 1995.
[18] **Chunming Li**, **Chenyang Xu**, **Changfeng Gui**, **Martin D. Fox**,Distance Regularized Level Set Evolution (DRLSE) and its Application to Image Segmentation, IEEE Transactions on Image Processing, 19(12), pp.3243-3253, 2010.
[19] **Maria Lianantonakis**, **Yvan R.Petillot**, Sidescan sonar segmentation using active contours and level set methods, IEEE Oceans-Europe, 1, pp.719-724, 2005.
[20] **WANG Xing-mei**, **YIN Gui-sheng**, **MEN Zhi-guo**, **YE Xiu-fen**, An improved method of underwater objects contours extraction based on level set, Journal of Harbin Instiitute of Technology, 42(4), pp.660-665, 2010.
[21] **Chunming Li**, **Chiu-Yen Kao**, **John C. Gore**, and **Zhaohua Ding**, Implicit Active Contours Driven by Local Binary Fitting Energy, IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp.1-7, 2007.
[22] **CAO Guo**, **MAO Zhihong**, **YANG Xin et al**. Optical aerial image partitioning using level sets based on modified Chan-Vese model, Pattern Recognition Letters, 29(4), pp.457-464, 2008.
[23] **SANG Enfang**, **SHEN Zhengyan**, **FAN Chang et al**, Sonar image segmentation based on implicit active contours, 2009 IEEE International Conference on Intelligent Computing and Intelligent Systems. Shanghai, pp.228-231, 2009.