THREATENING DEGREE ASSESSMENT METHOD OF SONAR TARGETS BASED ON MULTI-SOURCE INFORMATION FUSION

Bin Zhou[a,b], Xuejing Song[a,b], Qing Wang[a,b], Yuechao Chen[a,b]

[a]Science and Technology on Sonar Laboratory, Hangzhou, China
[b]Hangzhou Applied Acoustics Research Institute, Hangzhou, China

Bin Zhou
Pingfeng No.715, Liuxia Street, Xihu District, Hangzhou, Zhejiang Province, China
1986zhoubin@163.com

Abstract: *Multi-source information fusion can expand the detection range of a sonar system and improve the reliability and robustness of target recognition. To solve the problems of large transmission bandwidth, uncertain priori probability of target threatening degree discrimination, and inability to perform fusion processing within the framework of probability theory in the sonar target association using full spectrum feature information, a threatening degree assessment method for sonar targets based on multi-source information fusion is proposed in this paper. The method combines the target information output from low-frequency array, high-frequency array and non-acoustic sensor, to perform threatening degree assessment of low-frequency sonar target through multi-source information preprocessing, target track association, association information fusion and target classification. For target track association, an improved gray association algorithm is proposed, which can distinguish two different targets with the same track change trend but far away from each other. In the absence of a priori probability of threatening target discrimination, a multi-source information fusion method based on Dempster-Shafer evidence theory is proposed to solve the problem that probability theory cannot be effectively applied to information fusion processing, so as to eliminate non-threatening targets. Finally the Template matching technique is used to further improve the accuracy of target threatening degree assessment. The proposed method is verified by sea trial data of multi-source information, including low-frequency array data, high-frequency array data and automatic identification system(AIS) data. This work can meet the needs of low-frequency sonar target threatening degree assessment.*

Keywords: *sonar target detection, multi-source information fusion, threatening degree assessment method, Dempster-Shafer(D-S) evidence theory, template matching*

1. INTRODUCTION

Information fusion is a multi-level and multi-aspect processing procedure. It includes detection, correlation, combination and estimation of the multi-source data to improve the accuracy of state and identity estimation, and timely and complete evaluation of the importance of battlefield situation and threat[1-4]. In the field of sonar target detection, relative to single-array sonar, multi-dimensional (space, time) and multi-feature (frequency, electromagnetic) acoustic and non-acoustic sensor information fusion, can expand the detection range of sonar system, and improve the reliability and robustness of target recognition. The research of distributed and multi-base sonar detection technology is a hotspot in the field of sonar information fusion[5-6]. A single warship platform can also use the target information from different sonar arrays (bow array, flank array, towed line array, etc.) and non-acoustic systems (AIS, radar, magnetometer, etc.) installed on the platform for information fusion to evaluate the threatened targets. It can eliminate non-threatened targets and improve the efficiency of alert, and further improve the accuracy of target threatening degree assessment by combining Template matching technique. For the multi-source information fusion of single platform, the main processing flow includes: multi-source information pre-processing, target track correlation[8-9], and related information fusion. The existing processing methods have the following problems: (a) The pretreatment link lacks effective data collation and management methods for heterogeneous, sparse, granularity and other factors of multi-source information, (b) the amount of spectrum characteristic information required for target track association is too large to meet the engineering application conditions of real-time transmission[7], (c) The prior probability of threat target discrimination is uncertain, and it can't be fused under the framework of probability theory. [10-11], etc. Aiming at the above problems, this paper carries out relevant technical research, and forms a set of sonar target threat assessment method based on multi-source information fusion to meet the needs of low-frequency sonar target threatening degree assessment.

2. MULTI-SOURCE INFORMATION FUSION TECHNOLOGY BASED ON D-S EVIDENCE THEORY

The improved grey correlation method[12] is used to realize the correlation between the target of low-frequency array and the target of high-frequency and AIS target. Among AIS target, it is possible to find the corresponding associated low-frequency sonar target as a non-threatening target, and the probability of the non-threatening target can be roughly given by the correlation degree of the target. For example, when the target correlation degree is 1, the probability of judging a non-threatening target is also set to 1. The probability of judging a non-threatening target is not equal to 0, nor can it be simply set to 0.5 or any other parameter. This kind of uncertain estimation problem which can't give a prior probability can't be dealt with under the framework of probability theory. Aiming at this problem, this paper uses evidence theory to evaluate the non-threat degree. Evidence theory is a further extension of probability theory. It can map the hypothetical prior probability space to the hypothetical posterior probability space based on observation, overcome the disadvantage of requiring prior knowledge in the theory of absolute majority estimation, and use Dempster-Shafer synthesis formula to fuse multi-source information to obtain more accurate estimates.

The Multi-source information fusion method is validated by a sea trial data. The experiment lasts about 55 minutes. The multi-source input information includes the spatial energy spectrum of low-frequency array and high-frequency array and the target information of AIS. Firstly, the AIS target information is preprocessed and the final effective target data is

obtained as shown in Fig. 1. The horizontal axis is relative to the ship's azimuth (in the same azimuth coordinate system as the sonar output), and the vertical axis is time. There are 10 AIS targets, whose number has been marked in the figure. Then target tracking is carried out on the output space energy spectrum of low-frequency array and high-frequency array, and their target tracks are obtained, as shown in Fig. 2 (a), (b). Among them, there are 12 targets in low frequency array and 5 targets in high frequency array (including tugboat noise in this platform).

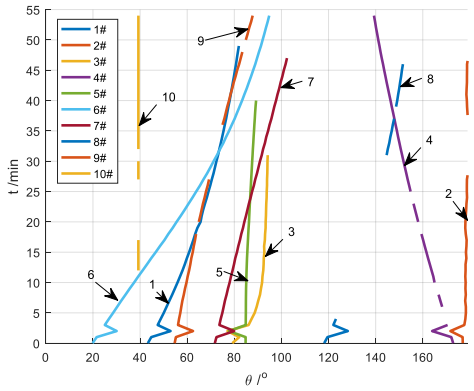
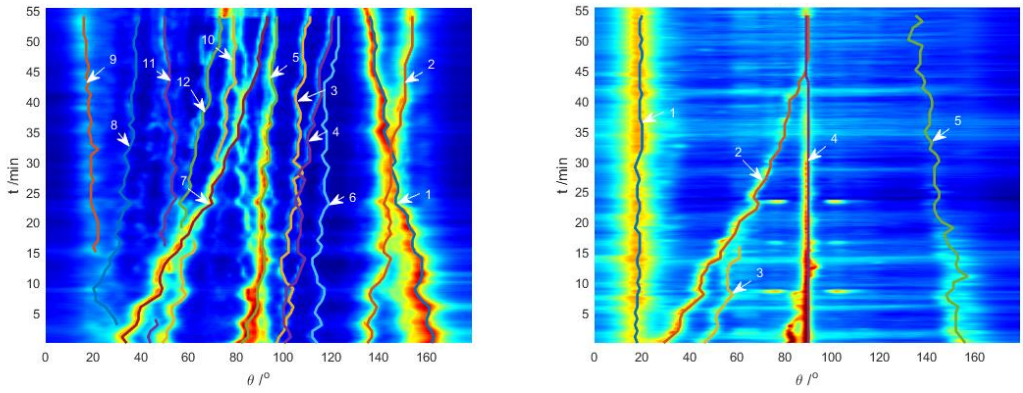


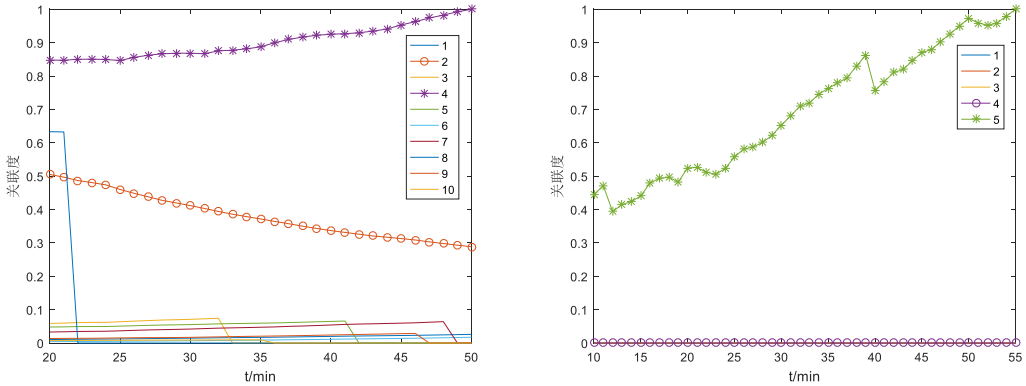
Fig.1: AIS target track.



（a） Low frequency sonar array *（b） High frequency sonar array*

Fig.2: Acoustical target track.

The improved grey correlation analysis method of target track is used to correlate the targets of low-frequency array and high-frequency array, and the targets of low-frequency array and AIS. Fig. 3 (a), (b) gives the normalized correlations of 1 # low-frequency array and all high-frequency array and AIS targets with time, respectively. It can be seen that 1 # target of low frequency array is strongly correlated with 4 # target of AIS and 5 # target of high frequency array.



(a) low frequency target and AIS targets (b) low frequency target and high frequency targets

Fig.3: Acoustical target track.

Then, multi-source information fusion technology based on D-S evidence theory is used to obtain the target non-threatening degree BPA value as shown in Table 1. Four non-threatening targets (5, 7, 9, 10) can be excluded. If all the low frequency targets are ranked according to the threatening degree, the 3#, 4#, 6#, 11#, 12# targets are in the forefront, so the subsequent target recognition can be mainly targeted at the 5 targets. Therefore, the non-threatening target is eliminated by the sonar target non-threatening degree assessment based on multi-source information fusion, which improves the alert efficiency.

Target Number	1#	2#	3#	4#	5#	6#	7#	8#	9#	10#	11#	12#
non-threatening degree	0.50	0.47	0	0	1	0	1	0.38	0.91	0.99	0	0

Table 1: List of non-threatening degree.

3. THREAT TARGET DISCRIMINATION TECHNOLOGY BASED ON TEMPLATE MATCHING

After eliminating non-threatening targets by multi-source information fusion method, the potential threatening targets are identified by Template matching technology. Firstly, input the beam-domain time-domain data of the tracking target, and accumulated a long time-domain signal, then analyzed the LOFAR spectrum. Then carried out Template matching by using the spectrum characteristics of threat targets in threat target template library. Finally, the evaluation results of target threat degree are given. Threat target discrimination technology processing flow based on Template matching is shown in Fig. 4.

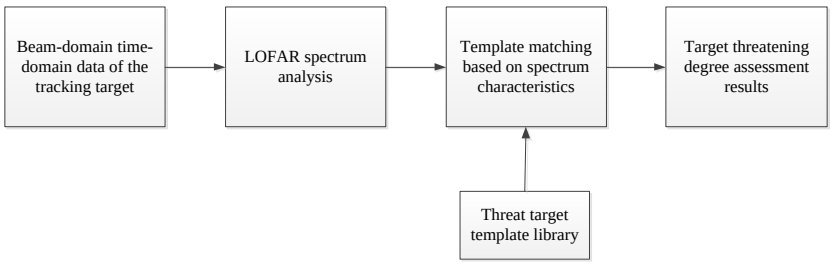


Fig.4: Flow chart of threat target discrimination technology based on template matching.

The results of the previous section of sea trial data processing are further analyzed to verify the threat target discrimination technology based on Template matching. Template matching is applied to the remaining targets after eliminating non-threatening targets. The target tracking single beam is divided into 150 samples, each sample for 0.3 minutes. The Template matching results are shown in Table 2. From the table, we can see that the low frequency target number 12 has the highest confidence. In fact, the 12# target in the sea trial is the simulated sound source of the threat target. The processing results are in accordance with the actual situation.

Target Number of low-frequency target	Total sample size	Distinguishing the number of threat targets	Distinguishing the Confidence of Threatened Targets
1	150	4	2.7%
2	150	0	0

3	150	0	0
4	150	10	6.7%
6	150	0	0
8	150	19	12.7%
11	150	24	16%
12	150	122	81.3%

Table 2: Results of Template matching.

4. CONCLUSIONS

In this paper, the target detected by low-frequency sonar array is taken as the target of threat elimination. Combining the target information output by high-frequency array and non-acoustic sensor, a threatening degree assessment method of sonar target based on multi-source information fusion is proposed. Using multi-source information fusion method based on Dempster-Shafer evidence theory, the credibility of non-threatening targets is given and non-threatening targets are eliminated. Combining with Template matching technology, potential threatening targets are identified to further improve the accuracy of target threat assessment. The method proposed in this paper is validated by sea trial data of low frequency array, high frequency array, AIS and other multi-source information. In this paper, the real-time processing of sea trial data has not been taken into account for the time being, so further related technical research will be carried out according to the actual engineering needs.

5. ACKNOWLEDGEMENTS

This study was founded by Young Elite Scientists Sponsorship Program by CAST(Grant No. 2017QNRC001) and the National Natural Science Foundation of China[Grant No. 61701450].

REFERENCES

[1] **Han Chongzhao, Zhu Hongyan, Duan Zhansheng**, *Multi-source Information Fusion,* Tsinghua University Press, 2010.
[2] **He You, Wang Guohong, Peng Yingyu, et al**, *Multisensor Information Fusion and Application* , Electronics industry Press, 2000.
[3] **Raffaele G, Parastoo A, Hassan G, et al,** Multi-sensor fusion in body sensor networks: state-of-the-art and research challenges, *Information Fusion*, 35, pp. 68-80, 2017.
[4] **Reda B, Didier C, Thanh-Long N, et al,** Multi-sensor information fusion: combination of fuzzy systems and evidence theory approaches in color recognition for the NAO humanoid robot, *Robotics and Autonomous Systems*, 100, pp. 302-316, 2018.
[5] **Sun Wei, Ge Yi-zhou, Yuan Yu-ting, et al,** Distributed Detection Fusion Used on Passive SonoBuoy, *Communication Countermeasures*, 35(3), pp. 23-27, 2016.
[6] **Lv Lin,** Multi-base sonar warfare in future anti-submarine warfare, *Electronic world*, 4, pp. 109-111, 2018.
[7] **Sergios Theodoridis, Konstantinos Koutroumbas,** *Pattern Recognition,* Academic Press, 2008.
[8] **Sun Qichen, Guo Weizhen, Yan Qianqian, et al,** A Multi-target Tracking Algorithm Based on Grey Relational Analysis, *Ludong University Journal*, 33(1), pp. 20-25, 2017.
[9] **Sun Wei, Shang Jintao, Zhu Kun,** A New Multi-targets Fusion Association Algorithms, *Acoustics and Electronic Engineering*, 123(3), pp. 1-3, 2016.

[10] **Wang Jie-gui, Luo Jing-qing,** Passive Tracking Based on Data Association with Information Fusion of Multi-Feature and Multi-Target, *Acta Electronica Sinica*, 32(6), pp. 1013-1016, 2004.

[11] **Kang Jian, Li Yi-bing, Lin Yun, et al,** Joint Probability Data Association Algorithm Based on Evidence Theory, *Systems Engineering and Electronics*, 35(8), pp. 1620- 1626, 2013.

[12] **Zhou Bin, Wangqing, Quan Hengheng,** Non-Threatening Degree Assessment Method of Sonar Targets Based on Multi-Source Information Fusion, *Journal of Unmanned Undersea Systems*, 26(5), pp. 439-443, 2018.