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A Summary of Knowledge Visualization of Underwater Acoustic Target Detection Literature

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Abstract: Underwater acoustic target detection technology is an important research direction in the field of underwater acoustic signal processing and sonar, and is one of the core technologies in marine applications such as environmental perception, ocean monitoring, resource exploration, and intelligence collection. In order to analyze the current research status of international underwater acoustic target detection technology, Web of Science's SSCI, SCI-E and HowNet are used as data sources, and 48 Chinese and foreign literatures on underwater acoustic target detection research published in 2010-2019 are used as analysis. Object, using a broken line chart to analyze the time cooperation network and space cooperation network of the research, using a pie chart to analyze the journal co-citation network density map, and use this to understand the direction of major research institutions in the field of international underwater acoustic target detection. This article summarizes the development status of underwater acoustic target detection technology, and introduces some new concepts, new methods and new trends in the research direction of underwater acoustic target detection in combination with actual scientific problems. Finally, it analyzes and prospects the development of underwater acoustic target detection technology. An important role for national security and economic development.
Keywords: Underwater acoustic target detection; sonar detection; intelligence; literature review.

1. INTRODUCTION

Challenges faced by underwater acoustic target detection technology. The underwater acoustic target detection technology refers to the signal processing technology that realizes the detection, tracking, positioning and identification of the underwater acoustic target within a certain range by receiving the radiated noise or scattered echo of the underwater acoustic target. Underwater acoustic target detection technology is an important research direction in the field of underwater acoustic signal processing and sonar. It is one of the core technologies in marine applications such as environmental perception, target monitoring, resource exploration, and intelligence collection [2]. It has always been the focus of research scholars at home and abroad. Hot issues of concern. The underwater acoustic target detection technology is constantly evolving and developing with the advancement of modern electronic information, signal processing and marine ship technology. The initial underwater acoustic target detection was mainly an active detection method using echo detection as a means [1]. After two world wars in the 20th century, passive detection methods using noise detection as a means gradually became the main underwater acoustic target detection system due to the requirement for self-concealment. In recent decades, with the development of modern mute technology, the detection range of passive targets has dropped sharply, which has prompted the combined active and passive detection method to become an important means of underwater acoustic target detection. At present, the development of underwater acoustic target detection technology is facing three challenges.

The target radiated noise and echo intensity are greatly reduced. With the rapid development of modern ship engineering technology, in the past 30 to 40 years, the radiated noise of ships has been decreasing at an average annual rate of 0.5-1.0dB [4]. The current level of radiated noise of the most advanced ships has been close to or even lower than Marine environmental noise. In addition, the advancement of advanced sound-absorbing materials technology has also reduced the intensity of ship echoes in the active detection of traditional operating frequency bands by 5-15 dB [4].

The marine environment noise has increased significantly. With the increasing frequency of human marine activities and seabed geological movements, marine environmental noise, especially low-frequency noise, has been increasing at a rate of 0.2-0.3dB per year in the past 50 to 60 years [4]. The United States uses the bottom observation acoustic array to continuously monitor the environmental noise level of the Northeast Pacific at 40 Hz, and the data obtained shows that from 1955 to 2011, the Northeast Pacific ocean environmental noise is showing an increasing trend [4].

The underwater acoustic effect of the marine environment has a significant impact. Due to the inhomogeneity of the ocean interface and the water medium [6], as well as the unique dynamic characteristics of the ocean front, vortex, current, etc., the water acoustic field presents complex random fluctuations in time and space, uncertain environment, inaccurate channels, and inaccurate parameters. Knowing and other characteristics make the underwater acoustic target detection performance change drastically with the changes of sea environment and time. The famous "afternoon effect" reflects this phenomenon [3]. In summary, the traditional underwater acoustic target detection technology based on statistical detection theory is difficult to meet the actual needs, and it is urgent to develop new concepts, new principles, and new methods for underwater acoustic target detection. This article will focus on the development status and new trends of underwater acoustic target detection technologies such as feature-based target detection, environmental adaptation-based target detection, distributed networked target detection, and intelligent target detection [5].

Literature review is the collection of literature in a specific field and topic, through sorting and analysis, to refine related issues or research progress. However, the literature review usually only classifies and analyzes the research content of the research object and lacks a comprehensive analysis of time, space, organization, etc. Scientific knowledge graph analysis is a bibliometric research method that has been widely used in recent years [7]. It can analyze the output sequence, spatial distribution, and cooperative institutions of the literature in all aspects. In 2018, Yang Yixin and others analyzed the development context of marine acoustic target detection technology from four aspects: passive detection technology, active detection technology, underwater communication networking and multi-source information fusion[1], and focused on the description of ocean acoustics. Research topics and trends of channel-based target detection. Through analysis, it is found that after decades of development, my country's underwater acoustic target detection technology has made great progress in both theoretical research and engineering applications [8], but there is still a big gap compared with the international advanced level.

However, because underwater acoustic target detection technology plays an indispensable role in protecting national maritime safety, it is more urgent to "speed up technological innovation and catch up with the advanced level" [10]. Facing the urgent needs of marine environment safety protection, building a distributed underwater detection network composed of active and passive detection nodes to perform multi-source acoustic information fusion is an effective way to improve underwater target detection capabilities [12], and it is also an effective way to detect marine acoustic targets. One of the important ideas for technological development. It is believed that with the strong support of the country in terms of talents and funds, through the hard work of the vast number of scientific researchers, the leap-forward development of underwater acoustic target detection technology can be realized. Through the chart analysis method, the literature on underwater acoustic target detection research is comprehensively combed and analyzed, and the future development direction of international underwater acoustic target detection technology is discovered, which provides a reference for the research of scholars in related fields.

2. METHOD AND DATD

This research document is derived from the core library of Web of Science (WOS). Select "Underwater acoustic target detection" or "Underwater acoustic target detection" as the search subject. The top 5 retained research categories are: Target detection, Underwater target (underwater target), Underwater acoustic channel (underwater acoustic channel), underwater acoustic detection, passive detection, the time interval is set to 2010-2019, the author selected 48 papers for reading, including 27 domestic documents, 21 foreign documents, and the basis for selective reading is the number of citations of the paper.

3. EXPERIMENTAL RESULTS

3.1 Time series output distribution

According to the statistical analysis of the annual literature number of underwater acoustic target detection according to the time series, the development process and the degree of attention of a specific topic can be found from the time point of view, as shown in Figure 1. It can be seen from Figure 1 that the number of documents related to underwater acoustic target detection included in WOS has maintained an overall increasing trend. From 2010 to 2015, the number of underwater acoustic target detection related documents included in WOS was less than 5, of which 4 were domestic documents during this period and 11 were foreign documents (all refer to the 48 documents selected by the author), indicating this period International research on underwater acoustic target detection technology has begun to take shape. Between 2015 and 2019, it reached its peak in 2018, with 16 articles published annually. The literature statistics for 2019 are as of the end of September, and the number of documents is 5, so the data for 2019 here are only for reference as of September 2019.

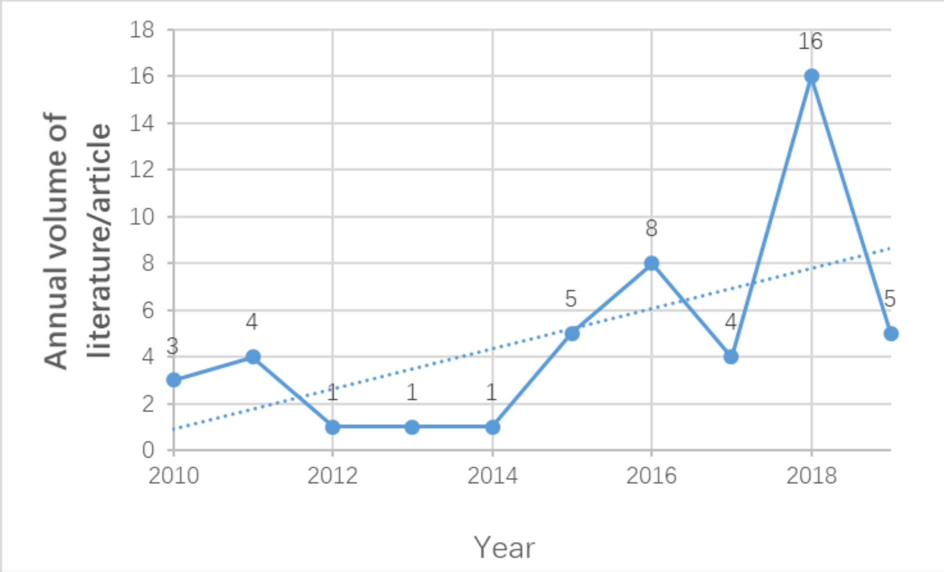

Fig. 1 Annual number of documents from 2010 to 2019

3.2 Spatial output distribution

The distribution of literature research strength includes the analysis of the source country or region and the analysis of the source organization. Among the 48 papers selected by the author, during 2010-2019, China accounted for 56.25% (27 papers) in the field of underwater acoustic target detection; the United States accounted for 20.83% (10 papers); the United Kingdom (6 papers), Japan (3 articles), Australia (2 articles). According to the analysis of the distribution map of the number of documents, the research in the field of global underwater acoustic target detection is mainly concentrated in North America (the United States), Europe, Asia (China, Japan) and other regions. Among them, when reading relevant American literature, it is obvious that the technology is more advanced and the knowledge coverage is more complete. As far as China is concerned, underwater acoustic target detection technology has just started. Most of the literature is written by industry leaders. There are not many schools involved in this subject in China. I hope that more scholars will participate in the development of this field in the future. In the national field, the marine field has been a contested area since ancient times. Therefore, the exploration of the underwater acoustic field rarely has cross-regional international cooperation like other fields, and most of it occurs in the same country or region. Research institutions mainly include universities, maritime-related enterprises and military institutions.

3.3 Journal analysis

It can be seen from the literature derived from Web of Science that there are 19 journals or publications that have published related literature on underwater acoustic target detection. Among them, the number of documents published in "Acoustic Technology" is the largest, reaching 9 articles, accounting for 18.75% of the total, followed by "Acoustics" (4 articles), "Journal of Underwater Unmanned Systems" (2 articles), and "Acoustics" (2 articles). Ship Science and Technology (2 articles), "Acoustics and Electronic Engineering" (2 articles). These journals can be regarded as authoritative journals in the field of underwater acoustic target detection.

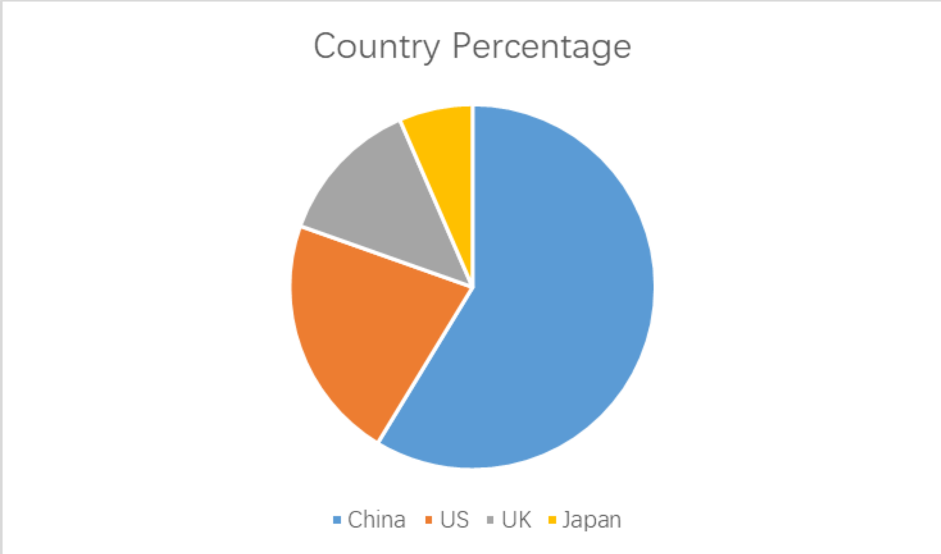

Fig. 2 Proportion of the number of documents in various countries

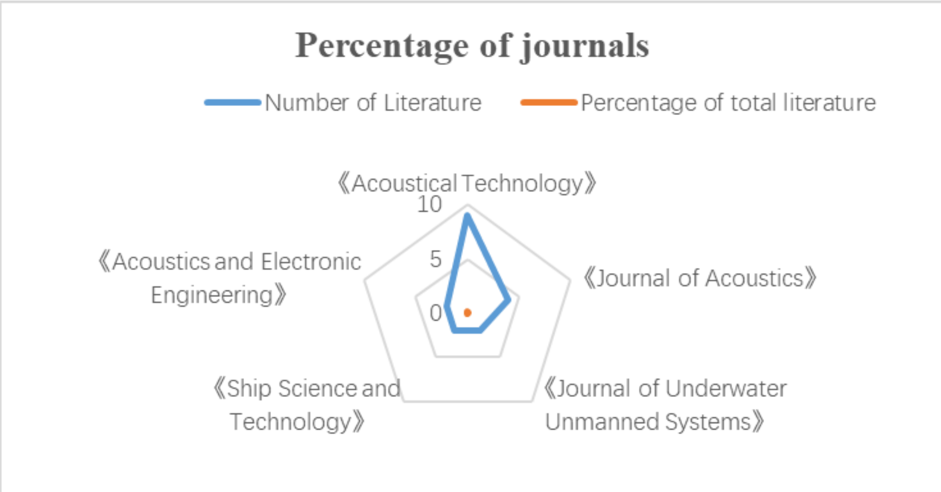

Fig. 3 Percentage of published journals in the literature

4. CURRENT STATUS OF DOMESTIC AND INTERNATIONAL RESEARCH

The author analyzed the research status of underwater acoustic target detection at home and abroad from the perspective of bibliometrics, and got the following conclusions. The author has read a total of 48 papers related to the field of underwater acoustics, including 5 acoustic propagation modeling, 7 submarine medium characteristics and its inversion, 5 interface scattering, 2 stratum exploration, 4 marine environment monitoring, internal 4 articles on wave and its sound propagation effects, 3 articles on ocean reverberation, 4 articles on target scattering, 4 articles on sonar and sonar signal processing, 6 articles on underwater acoustic sensors, 4 articles on other topics such as storm surge effects. Of course, it is impossible to draw any accurate conclusions only on the distribution of the number of papers read by the author, because in fact, there are still many relevant professional documents in major databases at home and abroad. It is different from what I said.

4.1 Current domestic situation

From the above situation, we can see the current development status of underwater acoustic target detection technology, and from the statistics given, we can roughly see the following points:

From the analysis of the acoustic essays, the proportion of papers engaged in the study of sound propagation in random media and scattering on undulating interfaces is not small [16]. Due to the difficulties of marine experiments in China, the research work in this direction is still very limited, and it is difficult to accurately understand the real application purpose of these studies. On the surface, a considerable proportion of these papers are discussing the undulations of the seawater medium layered interface in the marine environment, the signal distortion caused by the reflection and refraction of sound waves on these undulating interfaces, and the This may have a possible impact on target detection. In principle, for the undulating sea surface, the sound wave will have the Doppler effect when it is reflected on the sea surface [18], while for the layered seabed, the scattering and reflection of the sound wave on the layered interface at different depths will bring signal frequency Changes in composition [15]. However, how many of these effects are actually small, and for sound target detection and recognition, whether the impact is strong or weak, it is still difficult to accurately judge. Of course, due to the random fluctuations of the interface, it will bring about the scattering effect when the sound is reflected on the interface [21], which will bring errors to the use of acoustic signals to invert the parameters of the seafloor medium. To know the possible accuracy of the inversion results, it is also necessary to understand the effect of interface fluctuations on sound wave scattering [13].

With the decreasing working frequency of active sonar, the increasing range of its working distance, and the application of multistatic sonar: Therefore, regarding the long-range ocean reverberation modeling problem, the spare items for ocean reverberation in the case of receiving and transmitting separately Characteristic research, etc., has received great international attention nowadays [27]. However, most of the current research work on the attenuation law of ocean reverberation in the long-distance propagation is based on the basic assumption that the reverberation signal can be considered to be formed by a collection of scattered sound signals emitted by randomly distributed secondary sound sources.[20]. Although this assumption can bring great convenience in calculation, it can be assumed that the scattered sound has the required different directional characteristics according to different situations. However, the results obtained by using this assumption, especially in the case of separate receivers and transmitters, sometimes violate the principle of reciprocity of the sound field, and therefore have shortcomings [14].

In China, the Institute of Acoustics of the Chinese Academy of Sciences, Harbin Engineering University, Hangzhou Institute of Applied Acoustics and other institutions have conducted in-depth research on the technology of low-frequency and high-power transmitting transducers, and some corresponding transducer prototypes have been produced [19]. With the gradual maturity of low-frequency and high-power transmitting transducer technology, combining it with towed line array sonar for active and passive joint exploration is one of the future development directions of my country's low-frequency and high-power detection technology [22].

4.2 Status quo abroad

As early as the 1980s, the U.S. underwater acoustics community proposed that the focus of acoustic research needs to be gradually shifted to the shallow sea. Therefore, up to now, in the field of underwater acoustic research, great attention has been paid to the study of seabed characteristics [1]. In fact, except for the case of deep-sea sound channel propagation, the influence of the seabed on sound propagation is not negligible. Like in the tropical and subtropical waters of the Pacific Ocean, since the deep-sea channel axis is at a depth of 1,000 to 1,200 meters [2], even in seas with a depth of more than 3,000 meters, long-range sound propagation still relies on multiple seabed reflections. However, it is very difficult to determine the various acoustic properties of the submarine medium. It is impossible to use seabed sediment sampling. Under laboratory conditions, it is possible to reliably measure the values of various parameters of the sample when it is on the seabed; and different in-situ measurement methods have actually destroyed the seabed sediment structure. As a result, the real data of various parameters of the seabed are changed: some structures are complex and heavy, expensive, difficult to operate, and it is impossible to popularize them on a large scale [11]. So far, the most commonly used methods for measuring bottom quality are still various inversion methods. However, the credibility of the inversion results firstly depends on the accuracy of the hypothesis of the seafloor strata structure, and at the same time, there is also a need for corresponding verification methods for the measurement results. These problems are still hot issues that have not been fully resolved in the field of hydroacoustics today, and need to be studied in depth.

The research of underwater acoustic communication network started in the 1990s. With the continuous development of underwater acoustic communication technology and underwater modem technology, after the realization of point-to-point real-time communication, countries and regions such as the United States, the European Union, China, and Japan have successively begun the research of underwater acoustic communication network technology, born Some representative research projects, such as the Seaweb project in the United States and the persistent littoral undersea surveyllance network (PLUSNet) in the United States, and the framework programmes for research and development of the European Union. technological development) and the "Horizon 2020" plan (horizon 2020), etc. [23].

The Seaweb project pays attention to the reliability of the actual networking of underwater fixed deployment nodes, verifies the feasibility of long-term deployment of the network, and promotes the development of underwater communication nodes and the development of networking technology. The network nodes of this project are distributed in the range of 100~10000 km2, providing acoustic communication, detection, positioning and navigation functions. The autonomous underwater network system is composed of fixed surface buoy nodes, underwater fixed nodes and underwater mobile nodes. And use advanced networking protocol to complete the given task [26]. The Seaweb project started the actual underwater network test as early as 1998. It has been carried out for more than ten years so far, and it is currently the longest test time and the largest underwater network.

5. FRUTURE DEVELOPMENT TREND

Based on the above introduction to the development status, the author believes that the future development trend of marine acoustic target detection technology will be reflected in the following aspects.

5.1 Feature-based target detection technology

In a complex marine environment, facing increasingly lower target input signal-to-noise ratio conditions, how to improve the detection performance of underwater acoustic targets is an urgent problem in the field of underwater acoustic signal processing. From the perspective of the target, it is a natural choice to improve the performance of target signal reconnaissance and detection by studying the characteristics of the target signal in the generation, propagation and reception process, and using the target characteristics for high-gain processing [19]. At present, the development of feature-based target detection technology mainly includes four aspects.

Target detection technology based on inherent characteristic quantities [5]. The so-called inherent characteristic quantity refers to the part of the target radiation noise that is affected by the long-distance transmission of the ocean channel and changes little, or even if there is a change, the change law is known or controllable.

Vector signal processing method. The underwater acoustic field has both a sound pressure field and a vibration velocity field [10]. With the increasing maturity of vector hydrophones in engineering, the sound pressure and particle vibration velocity vectors can be obtained through the vector hydrophone at the same time, providing underwater acoustic target detection. Target sound field characteristics in more dimensions.

Target detection technology based on non-Gaussian and non-linear feature extraction [28]. Using modern signal processing tools such as Wigner-Vill distribution [29], wavelet transform, high-order statistics, and nonlinearity to analyze and extract features of received data, and then perform detection is also a relatively active research topic based on feature detection.

The processing method based on the tolerance characteristics of signal or noise relies on less prior knowledge of the propagation channel, and the signal or noise depends on the discriminative characteristics for processing to improve its tolerance [32].

5.2 Target detection technology based on environment adaptation

The complexity and variability of the marine environment make it difficult for classical signal detection and estimation theories to obtain good and stable performance in actual marine channels. Therefore, it is necessary to develop a signal processing technology that is combined with the underwater acoustic physics and adapted to it. Matched field processing (MFP) [21] is one of the representative technologies. It is the cross-correlation between the copy field calculated by the underwater acoustic propagation model and the measurement data to achieve target detection and positioning. MFP and later evolved matching mode processing (MMP), mode-based matched filtering (MBMF) and other methods [21] constitute the basis of the sound field space-time matching processing method. Due to the consideration of marine environmental factors, the performance of matching processing is theoretically superior to traditional detection methods based on statistical characteristics.

5.3 Distributed target detection technology

Faced with the problem of target detection with low signal-to-noise ratio in complex marine environments, it is difficult to meet current needs based on the existing single-platform, single-array underwater acoustic target detection technology. Since the underwater acoustic field is a three-dimensional structure [37], the use of multiple acoustic arrays distributed in space can obtain data of different observation angles and propagation paths of the target, which is beneficial to overcome the target signal noise caused by the non-uniform propagation of the sound field in time and space. Compared with the ups and downs, the use of multiple platforms and multiple arrays for distributed detection is a development trend in underwater acoustic target detection.

5.4 Intelligent target detection technology

In traditional underwater acoustic target detection, the target judgment performance is greatly affected by the operator's ability. Experienced operators are often easier to detect and judge targets in the background of low signal-to-noise ratio. In recent years, with the gradual application of unmanned systems such as underwater unmanned vehicles (UUV) and surface unmanned vehicles (USV) in the water [24], on the one hand, how to make unmanned systems operate unmanned or with less human participation. Under conditions, autonomous detection and discovery of targets has become a new problem in underwater acoustic target detection; on the other hand, with the rapid development of artificial intelligence technology represented by deep learning and big data, it also provides the development of underwater acoustic target detection technology in the direction of intelligence an opportunity.

6. CONCLUSION

After decades of development, my country's underwater acoustic target detection technology has made great progress in both theoretical research and engineering applications, but there is still a big gap compared with the international advanced level. However, because underwater acoustic target detection technology plays an indispensable role in protecting national maritime safety, it is more urgent to "speed up technological innovation and catch up with the advanced level". The 19th National Congress of the Communist Party of China put forward the basic policy of "building a maritime power"[1], which provides a new opportunity for the accelerated development of underwater acoustic target detection technology. Forge ahead, can realize the leapfrog development of underwater acoustic target detection technology.

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