Application of Side Scan Sonar Simulation Technology in Submarine Sediment Classification

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Abstract. In the aspect of seafloor sediment detection, underwater acoustic method has been concerned and used because of its high working efficiency and continuous abundance of data, and the processing function of echo intensity data is to obtain backscattering intensity data which only reflect the change of seafloor sediment. However, relying solely on multi-beam bathymetric system or scanning Sonar will lead to awkward situations where the resolution is insufficient or topographic factors affect the effective removal. In this paper, the purpose of this paper is to reconstruct the sound intensity of side scan sonar in the same area by using the seafloor terrain data obtained by multi-beam bathymetric survey, and then to form a sonar image which eliminates the influence of terrain. This paper discusses how to deal with the directional scattering intensity data of many kinds of data sources, such as multi-beam bathymetric system and scanning Sonar, so as to provide a service for the effective classification of seafloor sediment.

1. Introduction
The information of the seafloor of the sea seafloor has important application value in the aspects of marine engineering construction, marine fishery, marine resource development, marine scientific research, the maintenance of national marine rights and the use of underwater weapon and equipment. At present, the investigation of the seafloor substrate in China mainly adopts the direct sampling method, that is, the sampling point substrate sample is directly obtained by the sampler and the type of the sampling point substrate is described (GB/T 12763.8-2007). In the practical application, the distribution information of the seafloor substrate type is more needed, and the point-like sampling method of the direct sampling method restricts the regional description of the type of the seafloor substrate. First, direct sampling requires a large amount of human, material and financial resources, and is sometimes affected by factors such as equipment, water depth, or external environmental conditions, and the sample can be easily damaged or empty, and the type distribution of the substrate in the study area needs to be determined by means of interpolation and extrapolation. The precision of the interpolation and extrapolation points is limited, thus affecting the accuracy and representativeness of the classification results (Cui Gaosong, 2003; Langenhong, 2014). Therefore, it is very important to study the high-efficiency air-to-sea seafloor substrate classification technology to quickly master the distribution of the seafloor substrate.

The acoustic method is the most effective and rapid method for the classification of the seafloor substrate (Breslau, 1965; Jackson, 1984; Meng Jinsheng, 1986; Wang Runtian, 2002). The principle of
the invention is to use an acoustic transducer to transmit acoustic waves to the seafloor, and to determine the type and characteristics of the seafloor substrate by recording and analyzing the characteristics of the echo signals.

The currently used submarine-based acoustic sounding instruments are: side-scan sonar and multi-beam sounding system (Dyer, 1997; Clarke, 1992; Lurton, 1994). The device can obtain the information of the seafloor substrate without increasing the input, and has great value and application prospect without increasing the input. For single-beam, side-scan sonar and multi-beam submarine sediment classification, many experts and scholars at home and abroad such as Beaudin (2002), Hellequin (2003), Wu Ziyin (2005), Yang Fanlin (2003), Tang Qiuhua (2007), Zhao Jianhu (2008), Hamilton (2011), Jinshaohua (2011), Landmark (2014), Innocent (2015), Lark (2015) and Guperlet (2017) have made a great deal of in-depth study on data analysis, feature extraction and classification algorithms. And it enriches the algorithm model and the technical system of the classification of the acoustic seafloor substrate.

2. method for inversion of seafloor sediment by side-scan sonar

Due to the fluctuation of the seafloor interface and the irregularity of the spatial variation of the physical characteristics of the seafloor, the acoustic scattering of the sea floor is a random process. The study of the underwater acoustic scattering mainly includes two parts: one is the change law of the average reverse scattering intensity from the point of view of energy, and the second is to study the statistical properties of the scattering intensity by using the mathematical method of the random process, such as the distribution function and the energy spectrum (Darrell, 2007). The study of the underwater acoustic scattering is a huge subject. This paper focuses on the research status of the correlation between the intensity of the backscattering and the type of the substrate, which is the acoustic theoretical basis of the research on the classification of the bottom sediments. The sea bottom scattering intensity of the measured data at sea shows that its numerical value is affected by many factors, mainly including the acoustic frequency, the grazing angle (the residual angle of the sea bottom angle of incidence) and the bottom substrate.

![Figure 1. side-scan sonar and multi-beam joint measurement](image)

The statistical characteristics of seafloor backscattering intensity will provide additional information for acoustic seafloor sediment classification. At present, the models used to describe the statistical characteristics of seafloor backscattering are lognormal distribution, Weibull distribution, Rice distribution and K distribution (Jakeman, 1978; Oliver, 1984; Lyons, 1999; Abraham, 2004). Among them, K distribution can not only well describe the measured Sonar data, but also provide a physical explanation of the related backscattering phenomenon, which has a wide range of
applications. However, it should be pointed out that the theoretical model is only an approximation, and the statistical distribution of backscattering intensity may also be caused by the scattering enhancement of steep slopes. According to the research status of the correlation between backscattering intensity and seafloor sediment type, neither the variation law model of average backscattering intensity nor the statistical model of scattering intensity is one-to-one corresponding to the seafloor sediment type. Therefore, increasing the data source reflecting the characteristics of seafloor sediment and extracting more sediment characteristic parameters will help to improve the classification accuracy of seafloor sediment.

2.1. The Characteristics of Side-scan Sonar

Side scan Sonar is a kind of multi-purpose underwater acoustic detection equipment, one of the main uses is to obtain high-resolution seafloor Sonar images. Side scan Sonar records seafloor backscattering intensity on a time basis, which has the advantage of obtaining high resolution seafloor Sonar images, but in seafloor sediment detection, it also has its own defects, that is, it is impossible to distinguish whether the change of backscattering intensity is caused by the change of seafloor topography or sediment type. As shown in figure 2, when the seafloor is flat and the sediment is the same, the backscattering intensity varies smoothly with time; when the seafloor is uneven and the sediment is the same, the fluctuation of backscattering intensity reflects the change of seafloor topography (Sonar image can be used to show the microgeomorphology of the seafloor); when the seafloor is flat and the type of sediment changes, the change of backscattering intensity reflects the change of seafloor sediment (Sonar image can be used to detect the seafloor sediment); when the seafloor is uneven and the sediment type changes, the change of backscattering intensity is complex, and the influence of seafloor topography and sediment change on backscattering intensity can not be separated.

![Figure 2 Change of the Backscatter Intensity Caused by the Substrate and the Subsea Topography](image-url)
The above analysis shows that the side scan Sonar image has high spatial resolution and can better reflect the detailed changes of seafloor topography and sediment. However, due to the inseparability of Shanghai bottom topography and sediment information, the reliability of seafloor sediment classification results will be seriously reduced in the complex area of seafloor topography and sediment change.

2.2. Multi-beam seafloor sediment classification

Similar to the side-scan sonar, the multi-beam bathymetric system is also based on the analysis of the time-varying sequences of the echo intensities. In addition, in addition to recording the change information of the echo intensity over time, the multi-beam also records the angle information of the echo intensity, combines the water depth data of the multi-beam measurement, can carry out the correction of the influence of the submarine topography on the echo intensity. And acquiring the bottom reverse scattering intensity data which only reflects the characteristics of the substrate. The former characteristic parameter extraction is the same as the side-scan sonar, the latter mainly adopts the segmentation differential method (Hughes, 1997; Fonseca, 2007) and the model parameter global quasi-legal (Hellequin, 2003; Jinshahua, 2014) to extract features. The selection of the characteristic parameter extraction method is closely related to the factors such as the multi-beam data quality, the complexity of the submarine topography change and the type of the seabed substrate. When the curve is relatively smooth, the effect of the characteristic parameters is better when the curve is relatively smooth, and the effect of the characteristic parameters is better by using the sonar image when the bottom substrate is the complex of the gravel or the terrain.

A great deal of research has been carried out at home and abroad, and some significant research results have been made in the field of side-scan sonar and multi-beam bottom-bottom material classification. However, due to the randomness of the echo data, the redundancy of the extracted characteristic parameters and the one-sidedness of a single data source reflecting the characteristics of the seabed substrate will reduce the accuracy of the classification of the bottom substrate. Based on the multi-source seabed observation data, the paper has the potential to improve the accuracy and reliability of the classification of the bottom substrate. At present, the system has not been systematically studied and demonstrated at home and abroad. This restricts the development and application of the classification technology of the acoustic bottom substrate to a certain extent.

3. Matching fusion of seafloor topography and echo intensity data

The echo intensity data measured by multi-beam and side-scan Sonar are affected by the parameters of instrument system (sound source level, frequency, beam width, etc.) and spatial resolution, so it is difficult to fuse directly, but all echo intensities are related to seafloor topography. In the extraction process of "pure echo intensity information" reflecting the characteristics of substrate, it is necessary to remove the influence of seafloor topography. Firstly, the matching model between seafloor topography and echo intensity data is established.

In this paper, based on the multi-beam measured seafloor terrain data, taking the multi-beam and side-scan Sonar positioning point as the center, combined with the attitude, beam transmission angle and marine environment information, the position and incident angle of the beam to the seafloor are reconstructed, the matching algorithm and model of seafloor topography and echo intensity are established, and the correction scheme of seafloor topography influence of side-swept Sonar echo intensity is studied in combination with the relationship between seafloor backscattering and incident angle.

The influence of seafloor topography on echo intensity and its correction are established. For the purpose of seafloor sediment classification, the matching fusion algorithm of multi-beam and side-scan Sonar images is studied. On the premise of improving the position accuracy of side-scan Sonar images, the seafloor sediment characteristic information of Sonar images is highlighted to reduce or eliminate the influence of sediment-independent information, and a multi-source seafloor sediment classification image is formed.
4. Side scan Sonar Simulation for sediment Classification

The multi-beam and side-scan sonar have strong complementarity, and if the accurate digital information of the multi-beam depth-measuring system and the clear image information of the side-scanning sonar can be fused, the seabed can be qualitatively, quantitatively and comprehensively and fully explained. This will be of practical relevance and value.

Through the multi-beam bathymetric system, a large number of water depth data can be obtained, and then the seafloor terrain data model can be established. The bathymetric effect of side-scan Sonar system is weaker than that of multi-beam, and its advantage lies in high precision image information. If we can remove the topographic information related to sediment classification in the side scan image data, and then through other corresponding processing, we can get a seafloor sediment figure which only reflects the characteristics of the seafloor sediment. The image texture information with high side scan Sonar can be used to analyze the seafloor sediment which is naturally better than the inversion of multi-beam sound intensity information. Therefore, we can focus on how to remove the sound intensity correction value related to terrain information in the side scan image. Therefore, we simulate and reconstruct a side scan working scene based on multi-beam terrain, and form a simulation side scan image, which is compared with the measured side scan image. Because of the common substrate, the two images are bound to be strongly correlated. Then, there must be a model relationship between the residual sound intensity and the simulated ground sound intensity correction value after removing the topographic influence value of sound intensity on the simulation map. We transfer this model operation mode to the measured side scan Sonar image, and then the image drawn by the remaining sound intensity value will be more closely related to the bottom quality of the sea floor. Create better convenience for substrate classification. Then the key problem is the image simulation of side scan Sonar. In particular, the effective technique of angle of arrival estimation and the real-time variation of intensity of seafloor backscattering echo of scanning Sonar are studied.

In the simulation process, in addition to the Sonar equation, we should also consider the following problems: transmit pulse length and receiver bandwidth, transmit pulse length and receiver bandwidth, seafloor scattering intensity and reverberation target intensity, noise spectrum level, detection threshold, source level, in addition to reception gain and so on. Although complex, there are related methods and technical support. Therefore, the simulation method of side scan Sonar can help to eliminate the terrain factors on the Sonar image. This is actually a comprehensive use of multi-beam and side-scan Sonar two data sources.

5. Conclusion

A key factor in the classification of the bottom substrate using the multi-type seabed observation data is that it has a rich data source. At the same time, side-scan sonar and multi-beam measurements are required. In order to establish a correlation model with the bottom substrate, it is necessary to know the bottom substrate type of the survey area, and the type of the substrate should be as diverse as possible. At the same time, it is difficult to find the data of the above-mentioned requirements. In recent years, it has become more and more aware of the importance of the comprehensive survey and measurement. For example, the water depth data combined with the multi-beam measurement with the side-scan sonar image can reflect the shape of the submarine obstacle in detail. Therefore, many current measurement tasks require both side-scan sonar and multi-beam measurement to ensure the data source of the method. At the same time, the bottom substrate is an important parameter of the marine geographical environment. With the development of the comprehensive survey and investigation task, the data to meet the requirements will become more and more, and the necessary basic data guarantee is provided for the smooth development of the method. So, the method about “application of Side Scan Sonar Simulation in Submarine Sediment Classification” is viable.

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