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Review on Ultrasonic Techniques for Underwater Object Classification

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ABSTRACT: Underwater object classification is an attractive approach using acoustic remote sensing techniques due to its high coverage capabilities and limited costs as compared to manual method of taking samples from the seafloor. This review paper focuses on the characterization of underwater objects in a coastal environment using different ultrasonic techniques like multibeam echosounder (MBES), a single-beam echosounder (SBES) and sidescan sonar(SSS). Out of these ultrasonic techniques, MBES and SBES are, in general, high-frequency techniques providing information about bathymetry and backscatter for the upper part of the sea bottom. MBES systems provide this information with a better resolution due to the beam opening angle of typically 1 –3 , and high coverage. An SBES provides measurements directly underneath the ship only, but is widespread. For MBES underwater object classification is achieved through the Bayesian approach, employing backscatter measurements per beam. For the SBES, echo shape parameters of the transmitted signal are determined and are combined in a principal component analysis (PCA). Underwater object classification using these ultrasonic techniques is useful for a large range of applications, such as habitat mapping, cable laying, or mine hunting.

KEYWORDS: Underwater object classification, single-beam echosounder (SBES), multi-beam echosounder (MBES), backscatter measurement, sidescan sonar(SSS)

I.INTRODUCTION

The knowledge of oceanic environment is found to be necessary for many applications, such as coastal engineering, marine geology and marine biology[1]. Also, the environment needs to be known accurately when evaluating the acoustic propagation characteristics in shallow-water environments, e.g., for sonar performance assessment. Hence this motivates us for gathering of information about properties of the water column, under water objects that is the water–sediment interface and the deeper sediment layers. The classical technique applied for gathering of information for underwater objects is based on taking samples of the sediment but these techniques are very costly, time consuming and doesn’t give enough information as measurements are taken at point positions only. Hence this review paper is dedicated to methods allowed for underwater sediment classification using ultrasonic techniques such as multibeam echosounders (MBESs), e.g., [2]–[4]; single-beam echosounders (SBESs), e.g., [5]–[7]; and sidescan sonars (SSSs), e.g., [8]. The benefit of using these techniques for underwater object classification is that they are already in use for different marine applications and hence no need of additional hardware. Also frequencies employed for these ultrasonic techniques lie in the range of several hundreds of hertz, hence deeper sediment layers will be characterized. The only disadvantage of such systems is that these systems are typically mounted on board of a ship, and whatever sediment information obtained is only for the positions along the ship tracks.

This paper is organized as follows. Section II briefly gives the literature survey of the methods for underwater object classification. Section III gives an overview of the ultrasonic techniques such as SBES, MBES and Sidescan Sonars(SSS). Section IV deals with the acoustic data (two-way travel time and backscatter strength) obtained by the MBES. Here, backscatter strength data are used for the characterization of the sedimenovets. Then, in Section V, the echo shape parameters of SBES signals are analyzed by means of a principal component analysis (PCA). In Section VI, sidescan sonar are analyzed with the aim to obtain a picture of the sediment layering inside the water. Finally, the findings are summarized and conclusions are drawn in Section VII

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II. LITERARUE SURVEY

Underwater object classification methods can be divided in two categories: model-based methods and empirical methods[5]. Model-based methods translate echo signals directly into the physical properties of sediments. The advantage is that they take the physics into account to characterize the seafloor. The optimal method to modelling the acoustical signals is still subject to research. In addition, models in general are valid only for a certain range of frequencies and sediment types. Extension of these ranges might be required for certain applications. Model-based methods often require knowledge about system characteristics such as sensitivity, emitted signals, and directivity patterns. This information is not always available.

Empirical methods rely on the study of certain echo signal features that are correlated with sediment properties. A few of these features are usually combined using a clustering method. Each identified cluster is then associated with a particular type of sediment. The empirical methods are easy to implement, but have the disadvantage that it is not trivial to interpret the results. Grab samples could be of use to convert the acoustical classification results to physical properties of sediment.

III. UNDERSTANDING ULTRASONIC TECHNIQUES

As stated in previous section this paper focuses on the different ultrasonic techniques like SBES, MBES and Sidescan Sonar(SSS). Out of these three the singlebeam echosounder (SBES) is the earliest, most basic, and still the most widely used echo sounding device. This technique is used to take one-at-a-time measurements of the ocean depth at different locations. Recorded depths from SBES can be combined with their physical locations to build a three-dimensional map of the bottom surface.

Though SBES is simple and inexpensive to build, and easy to use and understand, it has a number of critical limitations that make it an inappropriate instrument for large-scale bathymetric survey work. Hence multibeam echosounder (MBES) were developed to serve the purpose of a large-scale bathymetric survey and to produce accurate depth measurements for many neighbouring points on the sea floor such that an accurate picture of the geography of the bottom can be established.

Both SBES and MBES are techniques for finding water depths using the time delays of acoustic echoes. But there is another technique which provides information about sea floor composition by taking advantage of the different sound absorbing and reflecting characteristics of different materials, such systems are called as sidescan sonar. Some types of material, such as metals or recently extruded volcanic rock, are very efficient at reflecting acoustic pulses. Clay and silt, on the other hand, do not reflect sound well. Strong reflectors create strong echoes, while weak reflectors create weaker echoes. Knowing these characteristics, one can use the strength of acoustic returns to examine the composition of the sea floor. Reporting the strength of echoes is essentially what sidescan sonar is designed to do. Combining bottom-composition information provided by sidescan sonar with the depth information from range-finding sonar can be a powerful technique for classification of underwater objects. In following sections we will see detail implementation of these ultrasonic techniques one by one for underwater object classification.

IV. UNDERWATER OBJECT CLASSIFICATION USING MBES

The characteristics MBES systems have proven to allow for characterization of the seafloor sediments. Many approaches deal with the classification based on MBES backscatter strength data by modelling the backscatter curves along a swath, thereby accounting for scattering at the rough water–sediment interface and volume scattering of the sediment body, e.g., [9] and [10]. When modeling backscatter strengths under different beam angles, the occurrence of non-uniform sediment types within a single swath has to be accounted for. In addition, the MBES needs to be well calibrated, which is not always the case [11]. Therefore, the approach towards sediment classification employing MBES backscatter strength data chosen for this paper employs the backscatter data per beam. It has been developed on the basis of a Bayesian approach as proposed in [12]. To optimize the method for the current application, characterized by water depths ranging from a few meters only to over a hundred meters, modifications to the original method were required.

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In this technique acoustic signals are sent and both the two way travel time and strength of scattered received signal for large number of beams is measured. Bathymetry is obtained from the (two-way) travel time as measured from the MBES per beam. The backscatter strength strongly depends on properties of the sediments such as surface roughness, density, sound speed, and volume inhomogeneties. Therefore, it can be employed for sediment characterization. Due to the high frequency used (300 kHz), the absorption length amounts to half a meter at maximum even for the prevailing fine-grained sediments. Therefore, the MBES data are not influenced by properties of the sediment body (deeper than 25 cm), such as sediment layering.

A. Mapping the Acoustic Classes

For characterizing the seafloor sediments, we use the backscatter strengths derived from the intensity of the backscattered acoustic signal. The approach selected for the current research utilizes the averaged backscatter strengths per beam. An advantage of this approach is its insensitivity to variations of seafloor type along the swath. In addition, imperfect calibration of the MBES system does not hamper the classification. The approach is presented in [12]. For the current research, it is extended. In [12], classification results, based on the MBES backscatter strengths, were presented when only a single beam was employed for the classification. Due to the relatively large distances between the tracks covered by the MBES for the data considered here, the method was modified such that a large number of beams were accounted for in the classification, thereby exploiting the high coverage capacity of the MBES

V. UNDERWATER OBJECT CLASSIFICATION USING SBES

The SBES system transmits an acoustic pulse towards the sea bottom and determines the water depth from the (two-way) travel time of the signal. Several features of the received signal such as total energy, time spread, and skewness, contain information on the sea bottom composition. These features are conceptually similar to the first, second, and third statistical moments. Such features can potentially be used for seafloor classification [13]. Although the three features (energy, time spread, and skewness) are intrinsically different in nature, they are statistically correlated. The PCA is adopted according to [14] to reduce the dimensionality of the extracted features while retaining most of the variation of the features. The PCA transforms a number of different but possibly correlated variables via linear combination into a smaller number of uncorrelated variables, called principal components. The first principal components account for as much of the variability in the data as possible. They are then fed to a cluster analysis based on the well-known K-means clustering algorithm [15].

The PCA has been applied to assess the three signal feature combinations that contain the relevant information for discriminating between different bottom types. Two (out of three) principal components, which show approximately 68% and 25% of the variability of the data, are used for clustering analysis. The first principal component is influenced by all three features, i.e., in decreasing order energy, time spread, and skewness, whereas the second principal component is dominated by the skewness and time spread. Based on the inspection of the first two principal components, the number of clusters with similar acoustic properties was set to four. The SBES is measuring only at angles close to nadir, whereas the MBES measurements used for the classification can be taken at all grazing angles.

VI. UNDERWATER OBJECT CLASSIFICATION USING SIDESCAN SONAR

Sidescan sonar employs much of the same hardware and processes as a conventional depth sounding sonar. Pulses are transmitted by a transmitter using a projector (or array of projectors), and hydrophones receive echoes of those pulses from the ocean floor and pass them to a receiver system. Where sidescan sonar differs from a depth-sounding system is in the way it processes these returns. This simplified picture does not consider what happens to the transmitted pulse after it first strikes the bottom, because a single-beam echo sounder is only interested in the time between transmission and the earliest return echo. Yet to a sidescan sonar, the first returned echo only marks when things start to get interesting.

In practice, sidescan sonar tend to mount both the line array and hydrophones on a towfish, a device that is towed in the water somewhat below the surface behind a survey vessel. As the survey vessel travels, the towfish transmits and listens to the echoes of a series of pulses .The echoes of each pulse are used to build up an amplitude versus time plot (or trace) for each side of the vessel. To adjust for the decline in the strength of echoes due to attenuation, a time-

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varying gain is applied to the amplitude values so that sea floor features with similar reflectivities have similar amplitudes. Eventually the noise inherent in the system (which remains constant) becomes comparable to the amplitude of the echo, and the amplified trace becomes dominated by noise. Recording of each trace is usually cut off before this occurs so that the next ping can be transmitted.

Each trace is converted into a series of gray shades on a plotting device. The shade of gray is determined by the amplitude (white corresponding to high amplitude, black to low amplitude, or vice-versa). The port and starboard traces are plotted next to and facing each other so that the ship's track is at the center of the picture, and subsequent pairs of traces are plotted in series to build up a "picture" of the bottom

VII.CONCLUSION

In this paper, different techniques to characterize the sediments in a coastal environment by combining different acoustic remote sensing techniques are presented. High-frequency systems, e.g., the MBES and the SBES, have proven to provide a consistent picture of the spatial distribution of the sediments over the entire area. However, due to the high frequencies involved, this distribution is valid only for the upper centimetres of the sediments. It was found that sediment samples could not be used for linking the acoustic classes to bottom type or mean grain size. Overall, it can be concluded that the MBES, SBES, and SSS measurements allows for a fast and efficient assessment of the sediment distribution in an area.

REFERENCES

1. J.-C. Le Gac and J.-P. Hermand, "MREA/BP07 cruise report," NATO Undersea Res. Cntr., La Spezia, Italy, Tech. Rep. NURC-CR- 2007-04 1D1, Dec. 2007.
2. L. Hellequin, J.-M. Boucher, and X. Lurton, "Processing of high-frequency multibeam echo sounder data for seafloor characterization," IEEE J. Ocean. Eng., vol. 28, no. 1, pp. 78–89, Jan. 2003.
3. G. Canepa and E. Pouliquen, "Inversion of geo-acoustic properties from high frequency multibeam data," in Proc. Boundary Influences in High Frequency Shallow Water Acoust., Bath, U.K., 2005, pp.233–240.
4. J. M. Preston, "Automated acoustic seabed classification of multibeam images of Stanton Banks," Appl. Acoust., vol. 70, no. 10, pp. 1277–1287, 2009.
5. D. D. Sternlicht and C. P. de Moustier, "Remote sensing of sediment characteristics by optimized echo-envelope matching," J. Acoust. Soc Amer., vol. 114, no. 5, pp. 2727–2743, 2003.
6. D. D. Sternlicht and C. P. de Moustier, "Time-dependent seafloor acoustic backscatter (10–100 kHz)," J. Acoust. Soc. Amer., vol. 114, no. 5, pp. 2709–2725, 2003.
7. P. A. van Walree, M. A. Ainslie, and D. G. Simons, "Mean grain size mapping with single-beam echo sounders," J. Acoust. Soc. Amer., vol. 120, no. 5, pp. 2555–2566, 2006.
8. J. M. Preston, A. C. Christney, W. T. Collins, and S. Bloomer, "Automated acoustic classification of sidescan images," in Proc. IEEE OCEANS Conf., 2004, pp. 2060–2065.
9. P. D. Mourad and D. R. Jackson, "High frequency sonar equation models for bottom backscatter forward loss," in Proc. IEEE OCEANS Conf., 1989, vol. 4, pp. 1168–1175.
10. C. de Moustier and D. Alexandrou, "Angular dependence of 12-kHz seafloor acoustic backscatter," J. Acoust. Soc. Amer., vol. 90, no. 1, pp.522–531, 1991.
11. D. G. Simons and M. Snellen, "A comparison between modeled and measured high frequency bottom backscattering," in Proc. Eur. Conf.Underwater Acoust., 2008, pp. 639–644.
12. D. G. Simons and M. Snellen, "A Bayesian approach to seafloor classification using multi-beam echo-sounder backscatter data," Appl. Acoust., vol. 70, no. 10, pp. 1258–1268, 2009.
13. P. A. vanWalree, J. Tegowski, C. Laban, and D. G. Simons, "Acoustic seafloor discrimination with echo shape parameters: A comparison with the ground truth," Continental Shelf Res., vol. 25, pp. 2273–2293,2005.
14. I. Jolliffe, Principal Component Analysis, 2nd ed. New York: Springer-Verlag, 2002, ch. 1–6.
15. G. A. F. Seber, Multivariate Observations. New York: Wiley, 1984,ch. 7.5.