CLASSIFICATION OF UNDERWATER SEDIMENTS USING ACOUSTIC SIGNAL PROCESSING METHOD

[PAPER ID: ICITER-D171]

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ABSTRACT:

Acoustic reflected signals are the most acceptable technology which carries the information of the underwater objects based on frequency, amplitude. The reflected echo carries information about the material characteristics based on absorption, reflection and refraction. In this paper a computer simulation program is developed to classify the underwater sediments based on the acoustic reflected signals. This computer simulation program also realizes the mechanism of acoustic signal propagating through the underwater layer media accounting for attenuation effects.

KEYWORDS: Sediment classification, Acoustic reflected signals.

INTRODUCTION:

Sediment classification can be performed using two approaches i.e. empirical approach and model based approach. In empirical approach using the bottom samples the sediments are classified whereas using model based approach acoustic backscatter signals reflected from different sediments are used for classification. The empirical approach is expensive and time consuming as they require dedicated ships and equipment. Therefore model based methods are preferred in which the reflected backscatter acoustic signals are analyzed and then the underwater objects such as sand, silt, clay etc. are classified. In this paper acoustic signal processing method is used for sediment classification. The main reason of using acoustic signals in underwater is that acoustic signals can travel over long distances as compared to electromagnetic waves [1]. In this paper the acoustic signal is modeled and then the different sediments are classified using reflected output signals and media characteristics.

SEDIMENT CLASSFICATION METHODS:

Sediment classification can be performed by acquiring various seabed images. A novel scheme of seabed image classification was proposed to identify three types of seabed sediments [1]. In this method texture features of seabed sediments were described by using fractal dimension and gray level co-occurrence matrix. Then an unsupervised learning algorithm, Self-Organizing Map neutral technique, was applied to analyze the seabed images. The experimental results indicate that the proposed texture feature descriptors were achievable and effective to categorize the three types of seabed images. Advancements in sonar processing and analysis allows for the more accurate and comprehensive inspection of the seafloor through high accuracy swath bathymetry, underwater seafloor classification systems, and improved systems for high resolution sub bottom profiling.

The response characteristics of acoustic data are correlated to bulk sediment properties such as density, porosity, and mean grain size, and sediment thickness through assessment of acoustic impedance, velocity, and absorption using proven Biot-based techniques [2]. The Biot theory was developed to explain acoustical behavior of sediment material accumulating on the seafloor.

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The Biot model estimates that sound velocity and attenuation in sediments will depend on frequency, on the elastic properties of the sediment grains and pore fluid, and on porosity, mean grain size, permeability, and effective stress.

There is an approach for processing sonar signals with the ultimate goal of ocean bottom sediment classification based on sonar data collected by the Volume Search Sonar (VSS), one of the five sonar systems in the AN/AQS-20.This technique is based on the Fractional Fourier Transform (FrFT), a time-frequency analysis tool which has become attractive in signal processing. Because FrFT uses linear chirps as basis functions, this approach is better suited for sonar applications. The magnitude of the bottom impulse response is given by the magnitude of the Fractional Fourier transform for optimal order applied to the bottom return signal. Joint time-frequency representations of the signal offer the possibility to determine the time-frequency configuration of the signal as its characteristic features for classification purpose[3]. The classification is based on singular value decomposition of the Choi William distribution applied to the impulse response obtained using Fractional Fourier transform. The set of the singular values represents the desired feature vectors that describe the properties of the signal. The singular value spectrum has a high data reduction potential. It encodes the following signal features: time-bandwidth product, frequency versus time dependence, number of signal components and their spacing. The spectrum is invariant to shifts of the signal in time and frequency and is well suited for pattern recognition and classification tasks. The most relevant features (singular values) have been mapped in a reduced dimension space where an unsupervised classification has been employed for acoustic seabed sediment classification. The theoretical model is addressed and then tested for sonar data.

A neural-network approach to classification of side scan-sonar imagery is tested on data from three distinct geoacoustic provinces of a mid ocean-ridge spreading center: axial valley, ridge flank, and sediment pond. The extraction of representative features from the side scan imagery is analyzed, and the performance of several commonly used texture measures are compared in terms of classification accuracy using a back propagation neural network. A suite of experiments compares the effectiveness of different feature vectors, the selection of training patterns, the configuration of the neural network, and two widely used statistical methods: Fisher-pair wise classifier and nearest-mean algorithm with distance measure. The feature vectors compared here comprise spectral estimates, gray-level run length, spatial gray-level dependence matrix, and gray-level differences [4],

In general, the classification methods can be divided into the physical and model-based methods. In physical methods features such as backscatter strength are derived from the bathymetric measurements are used for classifications. These features discriminate the sediments as belonging to different acoustic classes each with its own acoustic properties. These acoustic classes represent the different sediment types that are present in the survey area. However, independent information e.g., from the samples taken in the area, is usually needed to assign the sediment type, such as mud, sand and rock or sediment parameters, such as mean grain size, to the acoustic classes.

On the contrary, in the model based methods, we determine the sediment type with the comparison between modeled and measured signals or signal features. Where the sediment type or parameters are input to the model and the resulting signals in correspondence to each sediment are output of the model. Therefore in model based approach no independent information is required, since they provide the sediment type or properties for sediment type instead of acoustic signals.

UNDERWATER SIGNAL PROPAGATION AND SEDIMENT CLASSFICATION:

Acoustic signals are the most suitable signals used in the underwater as they can propagate over long distances. To realize the mechanism of acoustic

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signal propagating through underwater layer media a computer simulation program is developed for accounting attenuation effects. A seven layer underwater structure is assumed based on the data given in Table (1). The input signal x (t) as a representative of a typical seismic source signature analytically expressed by:

$$x(t) = 1360 * e^{-500t} - o.5 * e^{-15.3t}\sin(\omega t) \qquad (1)$$

Here t is the time and $\omega = 2\pi f$ is the frequency of the input signal x(t). In reflection seismology a source of energy produces a signal x(t) applied close to or on the water surface in reservoir. Mathematically, if the experiment is represented by a lossless wave equation, then all the signals within the media will be the time delayed scaled replicas of the source signal, x(t). Let y(t) be the resulting output signal of the model given by [5]

$$y(t) = \sum_{i=0}^{N} A_i * x(t - \tau_i) \qquad (2)$$

Here τ_i are the time delays and A_i are frequency dependent medium amplitude scale factors that vary with layer thickness and defined by

$$A_i = \alpha_i * e^{-\omega D_i} \qquad (3)$$

Seven layer is simulated to find the value of y(t), using convolution model given by Eq.(3) The model parameters are listed in Table I. Using the media characteristics and defined the input signal, the synthetic observation data in the layers is obtained. These waveforms indicate that the amplitude of the output signals is affected by the attenuation parameters of each sediment type. The media characteristics are measured based on the frequency independent amplitude scale factors. The frequency independent amplitude scale factor varies when there is variation in the damping factor and attenuation coefficient of the reflected signals.

Table 1. Material Characteristics

Material	α_i (mV)	g_i (mm)	α_i (db/ft)	d_i (ft)	τ_i (ms)
Silty Sand	0.061	0.10	2.80	27	0.20
Fine Sand	0.063	0.18	7.00	45	0.56
Very Fine Sand	0.051	0.09	4.50	48	0.74
Sand-Silty Clayey	0.032	0.03	7.30	56	0.80
Medium Sand	0.046	0.60	3.60	62	1.40
Coarse Sand	0.041	0.30	2.90	64	2.60
Clayey Silt	0.015	0.01	2.07	72	2.62

RESULTS AND DISCUSSIONS:

The acoustic input signal is a representation of the seismic source signal. This signal is propagated through the reservoir and then the output signals are reflected from various sediments.

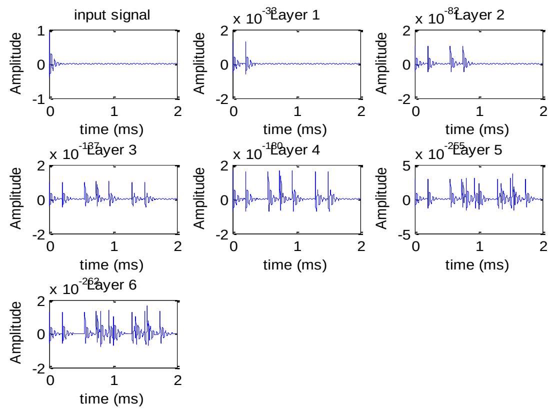

Figure 1-2 Input signal and the reflected acoustic signals.

It can be observed that reflected signals are attenuated as it is traversed through the different layers of sediments.

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of the reservoir sediments can be done using two approaches i.e. empirical and model based approach. **CONCLUSION AND FUTURE SCOPE:**

Classification The empirical approach is commonly used this method uses bottom samples to classify the sediments but the drawback of this method is that it is slow and expensive. The model based approach in principle eliminates the need of bottom samples. Here a theoretical model is used to predict the signal and then depending on the material characteristics and the reflected acoustic signals the sediment is classified. The model produces the range of that can correlate to the actual received signal. Hence the model based approach is used to classify the reservoir sediments which is done by measuring different material characteristics and reflected signals. The material characteristics are found to vary depending on the sediment type.

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