Seabed Classification Using Multibeam Echosounder Measurement Data

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Abstract. Multibeam Echosounder (MBES) utilizes acoustic waves emitted to the seafloor through a transmitter or transducer and records its reflective. The information obtained by MBES are depth data and the scattering value of the acoustic signal reflected by the object or the seabed, called backscatter. Acoustic backscatter can be used to classify objects or the seabed such as shipwrecks or seabed sediments. This study focuses on seabed classification using an acoustic backscatter obtained from the measurement at Alur Pelayaran Barat Surabaya (APBS). The data used in this research are acoustic backscatter from bathymetry data extraction and ground truth data of sediments. This study found the fine sand sediments with backscatter value -15.56 dB, and clayey silt sediments with backscatter value -24.36 dB. The correlations between backscatter and seabed sediments in study area were classified into four classes, clay class sediments with backscatter intensity range [(-33.81) – (-28)] dB, clayey silt sediments with backscatter intensity range [(-27.99) – (-23)] dB, sandy silt backscatter intensity range [(-22.9) – (-18)] dB, and sand class sediments with backscatter intensity range [(-17.99) – (-10)] dB. Based on the results data are known in the study area of seabed conditions dominated by sediments type sandy silt. Keywords— Multibeam Echosounder; Seabed Classification; Backscatter; Bathymetry; APBS.

1. Introduction

Bathymetry survey with multibeam echosounder (MBES) devices using acoustic waves. The working principle of the MBES emits acoustic waves and then the echo of the sound is recaptured by the transducer to find out the existence of underwater objects [1]. To detect the direction of the arrival of the signal reflected by the seabed, the transducer on the MBES uses three detection methods, namely the detection of amplitude, phase, and interferometry (angle). The information obtained from the measurement of MBES in the form of depth data from the reflection of acoustic waves and scattering values from sound signals reflected by objects or seabed called backscatter, this data has been used to predict sediment and habitat types [2].

Several studies have compared backscatter responses to truth data on seabed (e.g. sediment sampling, seafloor video images) to assess different acoustic technology capabilities in classifying types of seabed [3]. Backscatter depends on source level (SL) acoustic, grazing angle, underwater surface composition in the form of particle size, water content, magnitude of seabed roughness density, and echo volume in several depths [1][2]. Other studies have found that the low bathymetry slope (<1\degree) results in a backscatter response dominated by sedimentary properties, and the magnitude of water ripples also affects the roughness of the seabed [4]. The seabed which sedimentary mud produces gas above its surface which affects backscatter intensity [3][2].
2. Data and methodology

We conducted data in the form of depth and backscatter by doing measurement using Multibeam Echosounder Odom MB2 which supported by Teledyne PDS for processing bathymetry data. MBES utilizes active sonar to measure depth through acoustic wave propagation emitted until it’s received by the transducer [8]. The measurement area located in Alur Pelayaran Barat Surabaya (APBS). In this research area there always had ship activity passing across the shipping lane and the seabed dominated by dusty clay sediment with 0.3mm texture fraction size and 50% clay fraction percentage [6]. We conducted multibeam data from two area in APBS where the first area was required for calibration data that called Patch Test and the second area was sweep along APBS.

The measurement data conducted on 6th June, 2017 and must be accepted for special order data refers to IHO SP-44 2008 standard. Tolerance limits for accuracy of depth (D) are calculated using equation (1). To find out the quality of the measurement data, the average of the depth measurement (\( \bar{H} \)) is calculated using equation (2), then the standard deviation (\( \sigma \)) is calculated from the measurement results using equation (3) [9].

\[
D = \pm \sqrt{\left( a^2 + (b \times d)^2 \right)}
\]

\[
\bar{H} = \frac{\sum(H_n - H_{n-1})}{n}
\]

\[
\sigma = \sqrt{\frac{\sum(H_n - \bar{H})^2}{n-1}}
\]

where a denote the depth error constant, while b show error substitute factor another depth and d stand for depth on meter. While \( \bar{H} \) denote the depth average and \( H_n \) show depth lane.

The calculation of depth difference error value with a 95% confidence level that refers to IHO SP-44 in 2008 derived by 1.96 x \( \sigma \). Quality is tested based on the results of the depth difference error value. If the result below the tolerance obtained from the calculation using equation (1), then the measurement result is good and acceptable data [16]. To find out seabed sediment, ground truth data was taken in the measurement area. Sediment classification carried out using method of the American Society for Testing and Materials (ASTM) [13]. ASTM do the classification from the percentage of the sediment sieve in each filtered mass of particles, then put the results into the grain size table and determine the type of sediment texture. This method bring three types of sieve result, with consideration of percentage of sand, silt, and clay.

The seabed classification carried out with supervised classification method using samples of known identity to classify pixels of unknown identity. Samples of known identity are located within training areas, or training fields [15]. In this study, ground truth data of grain size sediment based on the location of backscatter [1] used to classify pixels of backscatter. However in this study, backscatter values obtained were corrected by adopting the linear contrast stretch equation [10] to understand the range of backscatter sediment values using equation (4), then the seabed classification is visualize with Arcgis software.

\[
BS_c = BS_i \times \frac{(BS - BS_{max})}{(BS_{min} - BS_{max})}
\]

where \( BS \) denote backscatter, \( BS_c \) show new backscatter, while \( BS_i \) denote the reference backscatter coefficient.
3. **Result and discussion**

3.1. *Patch test calibration*

Patch test calibration results are shown in Figure 1., there are two section presented each picture, on the right is a curve that describe the error between cross sections which if it has been calibrated it will be shown as U-shaped graphic and the picture on the left is represent a cross section between lanes. The error value is obtained from the calculation of each offset, where offset is the difference in mean depth between cross sections. Minimum errors are usually believed as the correct offset, but not always true [11].

![Figure 1. Patch test calibration presented for roll, pitch, and yaw.](image1.png)

3.2. *Seabed topography*

The depth data shown in Figure 2, uses negative value represented the topographic below the sea. The blue color described the depth getting deeper on the survey area. The considerable change in depth can be seen clearly on slope area where can be uses for the patch test. There can be seen area such as mounds that have different depth. The area was confirmed as wreck in APBS but had been covered by sediment, so the original shape of the ship was not clearly seen. The picture on figure 2, derived from backscatter signal and recorded as a function of time and and the intensity of each backscatter signal illustrates the irregularities of seabed [7].

![Figure 2. Seabed Topography.](image2.png)
3.3. **Backscatter**

The curve diagram states the amount of reflected and scatter value from the seabed and redistributed it waves captured by the sensor [14]. The soft bottom of the water (soft bottom) will produce a wide and low echo. In Figure 3, the curve shown by the view snippet is wide and low, it is possible to have a soft bottom [8]. In addition, the smooth and muddy waters will show an echo trace that has a narrow tailless tail where the acoustic energy will be reflected back to the transducer, and also absorbed by the mud substrate. While the echo trace from the rough bottom of the waters, the gravel mixture, will have a wide and tailed peak [12].

![Figure 3. Backscatter Intensity.](image)

The result of backscatter data extraction has the highest backscatter value of -10.25 dB, while the lowest backscatter value recorded of -88.22 dB. In general, the backscatter value in the APBS with a depth of 20 m are quite uniform, but in the 15 m depth range the backscatter has higher backscatter value. Backscatter value results is highly correlated with grain fraction size and sediment porosity, where it found sand sediment are reflectors that tends to be better than mud sediment for reflecting acoustic intensity [5].

3.4. **Seabed sample sediments**

The ground truth sample test was carried out by sediment fraction classification using the American Society for Testing and Materials (ASTM) sieve method, then the results of the sediment sieve percentage on each particle mass was determined using triangle texture of United States Department of Agriculture (USDA). The result of sediment test are shows on Figure 4(a), showing seabed sediments from sieve in the form of clayey silt or clay mud sediments. The results of the sediment test with sieve code, scored 41.76% for the type of clay, for silt for 22.13%, and for the type of sand for 33.61% with the type of fine. So that station two sediments are classified into clayey silt types.
3.5. **Analysis bathymetry measurement data**

This study takes measurements with overlapping 100% intersection between lanes. The value of each point that overlaps is calculated by the difference to get the standard deviation ($\sigma$). Then compared the accuracy of each data sample from equation (1). If the results are:

\[
(\sigma \times 1.96) < \text{Value of accuracy}, \text{ data is accepted, or } (\sigma \times 1.96) > \text{Value of accuracy}, \text{ data is not accepted.}
\]

The results showed that bathymetry measurements accuracy were accepted to be categorized into special order.

| IHO Constanta  | Value            |
|----------------|------------------|
| $\sigma$       | 0.04678675       |
| Z95%           | 1.96             |
| a              | 0.25             |
| b              | 0.0075           |
| $\sigma \times 1.96$ | 0.091702031 |
| Survey Data Accuracy | 0.289381418 |

3.6. **Seabed classification towards backscatter**

In this study two sediment samples were taken, the first station was sand sediment with backscatter -15.56 dB and the second station was clayey silt with backscatter -59.69 dB. The backscatter value obtained is compared with the previous research in Figure 4(b).

It can be seen that the backscatter of clayey silt has relative different value from the results of previous studies. The difference in value is possible because the area on this research location are heavily contaminated with many things, such as ship oil waste, river mouths. Another thing that can make the backscatter value in this study relatively different because of the high water ripples [4], in this study area reaches 30 cm. The research location is also a special order location, where dredging is
always carried out, so the high sediment deposition rate in the form of mud produces gas on its surface which affects the backscatter intensity [3].

Applying with equation (4), stretching the backscatter value that is owned against the value of the previous study, the backscatter value for sand has not changed or remains -15.56 dB. While for clayey silt changes to -24.36 dB. It shows on Figure 4(c), the previous backscatter value has makes it to -24.36 dB, so the intensity of clayey silt sediments on the same trends as the backscatter intensity of previous studies. Visualization of sediment classification against backscatter at research area shows on Figure 5, which has four classes; clay, clayey silt, sandy silt, and sand.

4. Conclusion

Accuracy of bathymetry measurement refers to IHO SP-44 in 2018, in this study has accuracy that is considered good and can be classified in special order. The result of the supervised classification in this study show that clay sediment have backscatter range -33.81 to -28 dB; clayey silt sediment have backscatter range -27.99 to -23 dB; sandy silt sediment have backscatter range -22.99 to -18 dB; and sand sediment have backscatter range -17.99 to -10 dB.

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