Comparative Analysis between Bathymetry and Backscatter Underwater Object Detection

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Abstract. Hydrography with respect to the various non-navigation purposes comprises the depictions of maritime features. For a progressively secure route and different applications, the emergence of sonar and swath echosounders currently enables more complete and a detailed description. It is absolutely difficult to find any features at any point in depth in such a way that the IHO has indicated the negligible size for the features to be found and estimated in a region. These activities and exercises are called detecting seafloor characteristics. For the purpose of distinguishing and recognizing, the features characteristic detection may also be utilized which are important to other navigators, for example, wellheads and mine-like attributes. The latter might not have been of navigational significance yet but are, nevertheless, of centrality to those concerned. In the event that the unwavering quality of multibeam on object identification study could be demonstrated or possibly its blunder could be found and has determined it’s constant. The multibeam could be broadly utilized for future ventures. By directing this examination study, the MBES data would be able to be evaluated and the capability extents of this data could be assessed. Thus, this study is aimed to analyse the accuracy of underwater object detection between bathymetry map and backscattered image derived from MBES data. The obtained results have shown that object detection from bathymetry map have slightly better visualization grade than backscatter images with a near perfection grade of 4.8.

1. Introduction

Hydrography as for the multiple non-navigation purposes comprises the descriptions of maritime features. For the sake of a more secure navigation and other applications, the emergence of sonar and swath echosounders right now enables more complete and a detailed description. For years and years, the seafloor classifications have been used in the mine warfare, but a broader usage evolution was made possible by an automated classification software where in particular fisheries and the resource sectors. It is important that anything that poses a threat to navigation be identified, especially things on the ocean floor, either natural or manmade, to ensure secured navigation. Any object on the seafloor is a feature defined such as that it is significantly different from the surrounding area; obstruction may be something from one isolated rock on a flat sandy ocean floor to a wreck [1].

These exercises are called seafloor characteristic detection intended for detecting and identifying the features characteristic that may also be used which are of interest to other navigators, such as wellheads and mine-like characteristics. Although may not have been of navigational importance but are, nevertheless, of significance to those concerned. By performing a regular sequence of sounding lines across the whole area the traditional survey would develop bathymetry of an area. Multibeam
Echosounder (MBES) or side scan sonar (SSS) coverage is being used for feature detection and providing information regarding seafloor classification. The detection of features is much more important than the acquisition of bathymetry in certain cases. A more positive check of its location and the least depth would usually be demanded as specific features that were identified on the MBES or SSS image [1]. For the low-resolution MBESs to be able to work in the deep water at a much lower frequencies, on average 12 kHz [2], shows that backscattering strength, records as the functions of the incident angles, would be the only way to measures parameter that can be used to make characterization on the interface of the acoustics properties. While for MBESs with the improved resolution that were designed for shallow depth with a greater frequency, typically at 100 kHz, would have additional information that is obtainable from the backscatters signals for better seabed classifications [3].

Quintessential examples of a backscatter images through a pleasant resolution to the fact that numerous texture and spatial groups of pixels that are clearly linked to variations on the characteristics of seafloor. Beyond its in-between level, the backscatter variableness within subareas permits the enhancement on the seafloor classification by means of statistics methods [4][5]. Backscatter image analysis in detail reveals numerous artefacts that demean images and corrupted the backscatter dimensions. Big reflectively echo, which leads to a high-level line beneath a ship track, then it would be linked to the backscatter physics where it should not be regarded, to be precise, as an artefact; meanwhile, it is a penalizing feature, hard enough to be deleted from the sonar images. Primary artefact is derived from the directional patterns of the array that are used for signal transmissions and receptions, which are generally not [3].

As of norm SSS is often applied to offshore engineering to acquire high-resolution seabed images and to detect underwater objects such as torpedoes, shipwrecks, aircrafts, mine-like objects, etc [6][7][8][9][10]. Essentially, the target detections and recognitions originating in the SSS images are mostly based upon the manual interpreting, and therefore its efficiency and accuracy would then have a great impact on the experiences of the sonar map reader [11].

Some people have used only multibeam echosounder for the survey to shorten the time and expenses to finish the survey. But the issue is that the data retrieved from multibeam echosounder have not been proven to be reliable. This is the question on the reliability of multibeam on object detection surveys. If the reliability of MBES data which is the sounding depth and backscatter on object detection survey could be proven or at least the error of it could be found and has determined its constant. The multibeam could be widely used for future projects.

As the advancement of multibeam echosounder systems maintains to provide greater amounts of raw soundings, the ability to process and manage such datasets turn out to be a concern as was the case during survey acquisitions and later in processing, delivery and archive of data. Ability to provide a cleaner dataset, reducing the processing of phase, is of tremendous advantages. The assimilation of echosounder and processing software, permitting the real time productions of bathymetry surfaces within the processing of software is investigated as the surveys continues [12].

2. Methodology

This study used the data acquired from multibeam echosounder, the data was able to produce two products which are the bathymetry and backscatter data. There are two main software that would be used to process this data which is the Qimera and Fledermaus Geocoder Toolbox (FMGT). Qimera is used to process the sounding data from cleaning the noise to producing the bathymetric map. As for FMGT software, it is used to process the backscatter data to produce an image of the backscattered data acquired. The methodology for this study includes data acquisition, data processing and data analysis as shown in Figure 1.

The data used in this study is acquired from Multibeam Echosounder. The data acquired consists of two types which are sounding data and backscattered data. Both data are taken simultaneously during the survey from the same equipment. The multibeam echosounder data that are acquired would be used and processed using QPS software. The software chosen is Qimera and FMGT where the output data would be then compared to make an analysis and determine its trustworthiness.
2.1. Qimera Data Processing

Qimera software is used to process the sounding data acquired from the MBES. By using the Qimera software and by following certain steps and procedures as shown in Figure 2, the final output for the data would be able to be acquired. The final output of Qimera software processing is the bathymetry mapping of the surveyed area.

Data cleaning is a method to remove noise from the multibeam echosounder data. There are 3 methods in removing the noise data. The first one is the 3D editor; this editor makes it easy to visualize the noise data for the user to identify it. By following the procedures for each method in data cleaning, the noise data would be able to be eliminated to the optimum level. This would help to improve the quality of the data and produce final output with precise data.
Second method is by using the Slice Editor, this editor projects the data in 2D by slicing the data and viewing it from the side of the surface. This method ensures that the noise data that are close to the surface can be identified. Lastly is by using the swath editor where the noise removal is done by each swath of the lines. This method is more like trimming the data to get a better surface projection.

2.2. Data Processing Using FMGT

The data processing using FMGT is as shown in Figure 3. After creating the project for the data processing of this research study, the source file that holds the backscatter data from the survey is added into FMGT software. By clicking at the Source header in the Source Files tab, the source file of the data would be able to be processed by the software. A few lines of soundings would be visible on the layout of the FMGT software. This shows that the source files are ready to be processed into a backscatter image.

![Figure 3. FMGT Workflow](image)

A mosaic is basically the backscatter image that are to be produced for the final product of this research study. To create the mosaic, by using the Automatic Processing tab, as the Backscatter Source is checked and set to Beam Time Series for the settings, the Mosaic icon in the tab is clicked to start the processing. Once the processing for the backscatter image is done, the histogram on the right side of the layout could be used to adjust the colourmap range to make the visualisations of the image better. The mosaic could also change its colour and appearance to a few colourmap to help in visualizing the underwater object on the seabed.

3. Results and analysis

The results for this study consist of the final product of depth data and backscatter data. The depth data final product is the dynamic surface created by using the Qimera software. This dynamic surface can be viewed in 3D and 2D models and it represents the bathymetry of the sounding data. As for backscatter data, by going through the processing using FMGT software, a backscattered image was able to be produced. This image is the final product of the backscatter data. The difference between both data is one represents the depth while the other represents the material. From both final products, an analysis can be done to compare the dimensions and measurements of the underwater object detected. The methods that are to be used to compare the dimensions and measurements of the underwater object is by using the coordinate of the point. This is to ensure that the measurements are more precise. Since the backscatter data could only be projected in 2D model, only the 2D model of the bathymetry map would be used for this method. Other than this is the analysis in comparing visualization of the two data. Here the capability of each data to help visualize the underwater object would be compared. With the bathymetry data which consist of 2D and 3D data will be compared with the backscattered image which only consists of 2D data only. The comparison is based on which data set helps in identifying the object better.
3.1. Bathymetry map
The final output for sounding data that are processed using the Qimera software is a bathymetric map as shown in Figures 4 and 5. The bathymetry maps are produced by the Qimera software using the dynamic surface which is the special properties of the software. This dynamic surface software automatically updates its surface from the editing done during the processing.

![Figure 4. Dynamic Surface 2D Model. Top-view (left), Side-view (right)](image)

![Figure 5. Dynamic Surface 3D Model. Top-view (left), Side-view (right)](image)

3.2. Backscatter Image
A backscatter image is produced as the final output of FMGT software processing using the backscatter data of the surveyed area. The image produced by FMGT software can also have the image color and appearance be changed to improve the visualizations of the underwater object on the seabed. The color range of the image is based on the intensity of the sounds reflected by the surface. It differentiates the materials and characteristics of the reflected surface. Hence, for the backscatter image, there are 2 types of color map that are produced to aid the visualization of the object as shown in Figure 6.

![Figure 6. Backscatter Image. Side-scan Copper (left), Gray (right)](image)

3.3. Measurement Comparisons
There are 4 shipwrecks identified from both final products of the processing which is the 2D bathymetry map and backscatter image. By allocating point numbering to every part of the ship that is visible and
easy to be identified as shown in Figure 7, the coordinate of the points would be taken from both final output and the differences are calculated. The distance between the points is computed by using the distance coordinate geometry method of x and y. The measurements and dimensions between both data will be compared to each other.

![Figure 7. Point Allocations for Ship A, B, C and D](image)

**Table 1. Measurements of Shipwrecks Dimensions**

| Points   | Distance (m) | Bathymetry | Backscatter | Diff |
|----------|--------------|------------|-------------|------|
| 1 to 2   | 29.48        | 29.88      | 0.39        |
| 3 to 4   | 6.17         | 5.82       | -0.35       |
| 7 to 8   | 6.00         | 6.21       | 0.21        |
| 9 to 10  | 5.89         | n/a        | n/a         |
| 5 to 6   | 5.57         | 6.04       | 0.47        |
| 3 to 5   | 16.97        | 16.68      | -0.30       |
| 4 to 6   | 16.57        | 16.69      | 0.12        |
| 3 to 6   | 17.83        | 17.11      | -0.72       |
| 4 to 5   | 17.71        | 18.29      | 0.58        |
| 11 to 12 | 55.15        | 55.18      | 0.03        |
| 13 to 14 | 6.49         | 6.04       | -0.45       |
| 15 to 16 | 6.45         | 6.09       | -0.35       |
| 17 to 18 | 6.67         | 6.22       | -0.45       |
| 19 to 20 | 5.77         | n/a        | n/a         |
| 21 to 22 | 5.59         | n/a        | n/a         |
| 23 to 24 | 5.77         | 5.95       | 0.18        |
| 13 to 16 | 15.50        | 15.40      | -0.10       |
| 14 to 15 | 15.37        | 15.13      | -0.24       |
| 16 to 17 | 13.34        | 12.95      | -0.39       |
| 20 to 23 | 11.29        | 10.50      | -0.79       |
| 25 to 26 | 61.95        | 60.98      | -0.97       |
| 29 to 30 | 6.40         | 6.42       | 0.02        |
| 33 to 34 | 6.55         | 5.59       | -0.95       |
| 28 to 29 | 18.33        | 17.77      | -0.55       |
From the obtained results as listed in Table 1, both final products of the data would be compared with each other for its coordinate of points allocated on the shipwrecks, measurements distance between points and visualization of dimensions. There are three final products that are produced for this study which are the 2D Bathymetry map, 3D Bathymetry map and Backscatter Image.

Point coordinate analysis compares the coordinate of allocated points on the 2D Bathymetry map and Backscatter Image. From the calculations done, it shows that the accuracy of the data of both products are 0.23m for X and 0.13 for Y excluding 3 points out of 36 allocated points that could not be identified in the backscatter image.

Measurements point to point compare the final point coordinate comparison, both product measurements are compared with each other to get the difference in measurements from the data. From the sum of the differences in measurements divided by the number of measurements, the accuracy of the data could be assessed. The accuracy for the point to point measurements are 0.22m.

3.4. Visualizations Comparison

Table 2. Ship A Visualizations Grading

| Dimensions | Visualization |
|------------|---------------|
|            | 2D Bathymetry | 3D Bathymetry | 2D Backscattered |
| Length     | 5             | 5             | 4               |
| Width      | 5             | 5             | 4               |
| Depth      | 0             | 5             | 0               |

Table 3. Ship B Visualizations Grading

| Dimensions | Visualization |
|------------|---------------|
|            | 2D Bathymetry | 3D Bathymetry | 2D Backscattered |
| Length     | 5             | 5             | 5               |
| Width      | 5             | 5             | 4               |
| Depth      | 0             | 5             | 0               |

Table 4. Ship C Visualizations Grading

| Dimensions | Visualization |
|------------|---------------|
|            | 2D Bathymetry | 3D Bathymetry | 2D Backscattered |
| Length     | 5             | 5             | 5               |
| Width      | 5             | 5             | 4               |
| Depth      | 0             | 5             | 0               |

Table 5. Ship D Visualizations Grading

| Dimensions | Visualization |
|------------|---------------|
|            | 2D Bathymetry | 3D Bathymetry | 2D Backscattered |
| Length     | 5             | 5             | 5               |
| Width      | 3             | 4             | 2               |
| Depth      | 0             | 4             | 0               |

Finally, the visualizations of the 3 dimensions of the shipwreck are graded to a range of 0 to 5 where 0 means not visible and 5 as excellent visualizations as shown in Tables 2 to 5. The first visualizations
of the dimensions to be compared are between the 2D models only where the visualizations of the depth dimensions would be excluded. The average grade of 2D bathymetry map for the visualization of the two dimensions length and width of each shipwreck is 4.8 while the average visualization for backscatter images is 4.1.

4. Conclusions
This study shows the comparative analysis between bathymetry map and backscatter image for underwater object detection using three analysis methods which are point coordinate analysis, measurement point to point analysis and visualization comparison analysis. From the obtained results, the average accuracy for the point to point measurements is 0.22m. The final product of 2D bathymetry maps have slightly better visualization than backscatter images with a near perfection grade of 4.8 out of the perfect 5. As for the second visualization comparison, the 3D bathymetry map is included in the comparison and the depth dimensions of the shipwreck are also graded. Since only 3D image could project the depth dimensions, the 3D Bathymetry map are the best data that projects all dimensions of the shipwreck as its visualization average grade are at 4.8 while the 2D Bathymetry map is at 3.2 and backscatter as the least visualization projections at 2.8 on average.

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