GEOCORRECTION OF 3^D BOTTOM IMAGES FROM MULTIBEAM SONAR RECORDS

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Abstract

The 3^D seafloor images produced using multibeam sonar data, due to the influence of various sources errors during the acquisition and processing, do not comply exact with true geographical positions and need geocorrection prior to overlaying on a nautical map. Some geocorrection procedure was proposed and applied for processing the multibeam data of bottom relief in order to remove the influence of the simulated distortion. Two cases of 3^D seafloor mapping were investigated, viz.: with and without periodical fluctuations generated by ship rolling. In the both cases of presented results of numerical calculations, the obtained algorithm performance is acceptable in the first stage of the investigation and allows to some extent for removing the error influence from bottom relief.

Introduction

Application of seafloor mapping and imaging is very important in many areas including marine navigation, hydrography and GIS systems. This is especially attractive when mapping of the seabed is performed using multibeam sonar systems, which can map a bottom within the resolution of 1 meter. Increasing amount of digital (raster) and very precise echo records from multibeam sonar have enhanced the potential of computer modeling of the marine environment to improve our understanding of the bottom processes. A mapped bottom area typically contains bathymetry data along with navigation information (e.g. UTM coordinates), allowing for further visualisation. In the last decade, the extensive use of multibeam sonars allowed for mapping of wide areas.

However, usually the 3^D bottom images, as the result of merging multibeam sonar data from different transects and due to the influence of various sources errors during the acquisition and processing of acoustic data, do not comply exact with true geographical positions. Therefore, while overlaying the bottom multibeam data on a nautical chart, the geometrical correction is necessary. This investigation concerns the problem of spatial correcting of multibeam data describing a bottom relief, and presents a simple algorithm used for this purpose. The algorithm was tested by the simulation of local distortion of bottom relief data which had been obtained from multibeam bathymetry, and then applying the correction procedure and comparison of the result with the original.

Errors in 3^D seabed mappind using multibeam sonar echoes

There are many reasons of errors occurring in multibeam data acquisition and processing, influencing the quality of being finally obtained images of bottom relief, and causing the divergence between them and features on a nautical chart. So, raw echo records from multibeam sonar are directly used rather rarely, as they are typically interfered by many sources of noise, spikes and outliers, which affect the quality of contours representation and slope of bottom lines.

The noise sources may include breaking waves, rain, thermal phenomena, seismic activity, ships, marine animals, and so on. This is so called an ambient noise. However, the error sources of a great importance are: ambiguity of heading (either determined from gyro or GPS), velocity and position from GPS, together with roll, pitch and yaw of a ship and acceleration measurements. As turns out, the data provided by peripheral units play the crucial role in the precise positioning and application of correctors to the multibeam sonar bottom relief mapping.

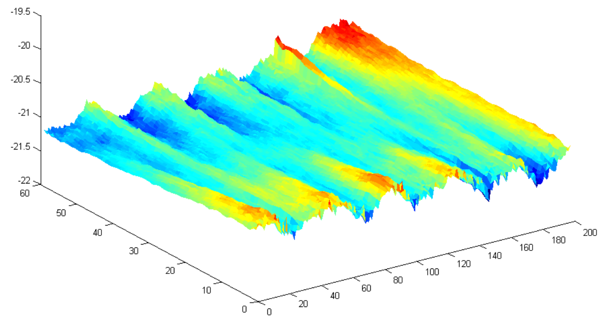

Figure 1 : Periodical errors in seafloor image due to rolling

An error in bathymetric data is a function of several parameters. Roll errors are more significant then errors in pitch – see Fig 1. The error is especially important for greater beam angels. For the relatively slow dynamic of the measured signal, as is in a bottom depth case in fact, very dense raster measurements from the multibeam sonar perfectly fit the application of digital Kalman filter algorithm.

Additionally, some errors occur due to an instrumentation temporary error, what has great impact on an overall data quality.

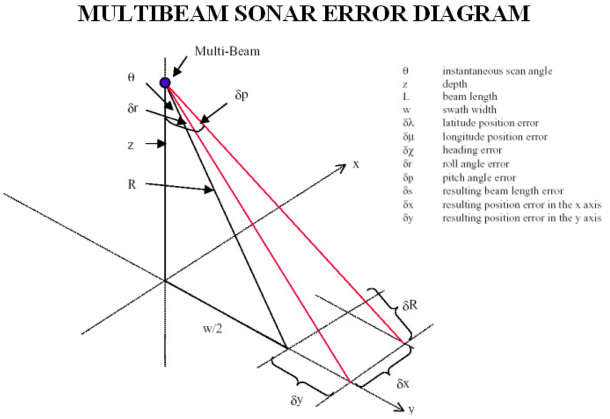

Figure 2 : Multibeam sonar error digram, after [4]

Some of a multibeam sonar errors are presented on multibeam sonar error diagram in Fig. 2.

Depending on the character of error source influencing a bottom relief data, a different algorithm have to be used for correction.

Geocorrection Algorithm

In the presented investigation, the following algorithm was used for geometrical correction of the multibeam images of seafloor relief:

$$x'_1 = x_1 + \sum_{n=1}^{N} \frac{1}{1 + A(x_i - x_{1n})^2} \cdot (x_{0n} - x_{1n}) * \cos\left(\frac{(y_i - y_{1n}) * 0.5\pi}{(y_{0n} - y_{1n})}\right)$$

$$y'_1 = y_1 + \sum_{n=1}^{N} \frac{1}{1 + A(y_i - y_{1n})^2} \cdot (y_{0n} - y_{1n}) * \cos\left(\frac{(x_i - x_{1n}) * 0.5\pi}{(x_{0n} - x_{1n})}\right)$$

$$z'_1 = z_1 + \sum_{n=1}^{N} \frac{(z_{0n} - z_{1n})}{(1 + A(x_i - x_{1n}))^2 (1 + A(y_i - y_{1n}))^2}$$

where:

$[x_i, y_i, z_i]$ – seafloor points coordinates, $i = 1, 2, ..., M$,

$[x_{0n}, y_{0n}, z_{0n}]$ – original reference points coordinates, $n = 1, 2, ..., N$, $N << M$,

$[x_{1n}, y_{1n}, z_{1n}]$ – identified reference points coordinates, $n = 1, 2, 3,..., N$,

A – coefficient depending on area size and on distances between reference points.

The main advantage of the algorithm is its capability of distortion correcting for the relatively great areas.

Testing the algorithm

The actual multibeam sonar data was processed. Due to the problem with identifying of real submerged objects from available data, the distortions was simulated and then corrections were applied. The results were compared to not distorted data.

Description of sonar data

Seafloor data was acquired from SeaBat 8101 multibeam sonar in Gulf of Gdańsk area. The site location is showed in Fig. 3. More important acquisition parameters were as follows:

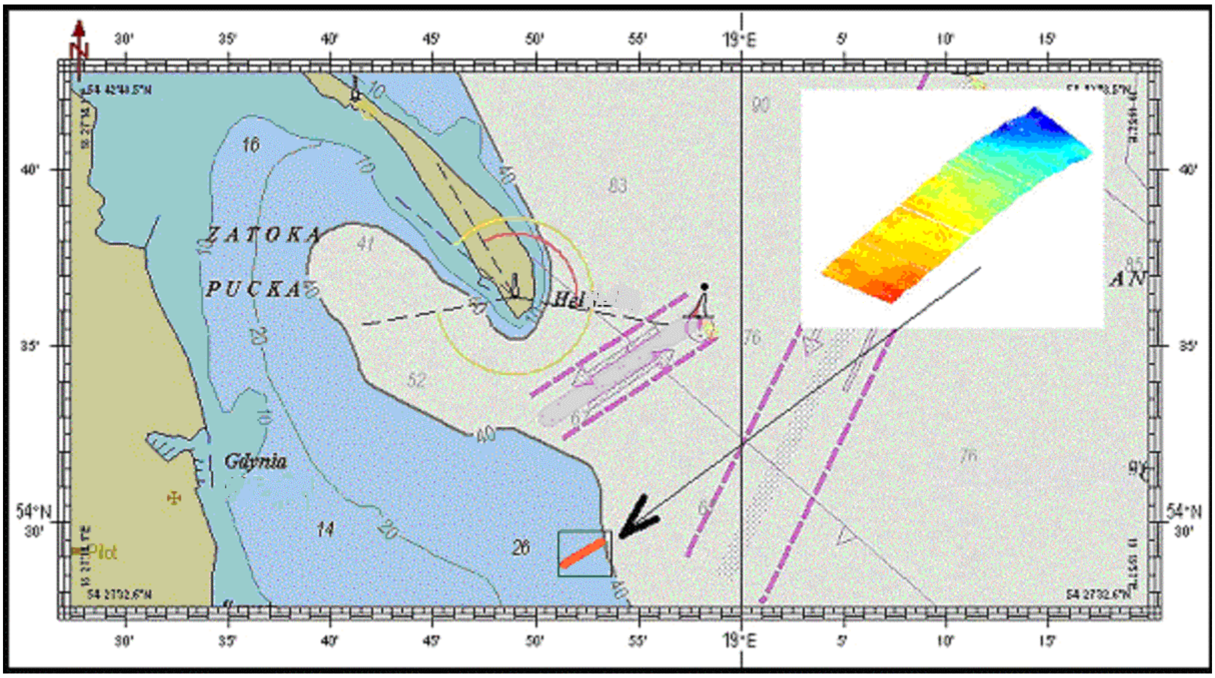

Fig. 3 : Sonar data acquisition site

- 50 degree Wide Swath Coverage
- Up to 300 m Range Capability
- Phase and Amplitude bottom Detection
- Depth measurement range: 0.5 to 500 metres
- Range resolution: 1.25 cm
- Max. update rate: 30 swaths per second
- Frequency: 240 kHz
- Number of beams: 101
- Beam size: 1½° x 1½°
- Total swath coverage:7.4xWater Depth (150°)

Simulation of distortion

Two components of distortion simulation was used and added to the bottom surface in both considered cases:

1) a local component of a Gaussian function shape and dimension of meters,
2) white noise of rms equal to a 0.5 m range.

Numerical results

The following procedure was applied. Firstly, the single reference point was arbitrarily set, and then the introduced correction algorithm was applied.

Two cases of sonar data patch was processed:

1) seafloor relief with periodical roll error clearly visible,
2) seafloor relief without periodical roll error.

The Kalman filtering was applied to both datasets prior to the described calculations.

Fig. 4 presents the successive stages of multibeam bathymetric data processing for both cases (case 1 – left, case 2 – right). In all pictures, all axes are in meters.

While comparing Fig. 4b with Fig. 4c, it is visible in both cases that after applying the geocorrection algorithm, the difference between corrected surface and not distorted surface is significantly lower than the difference between distorted surface and not distorted surface. What is more, it the case 1, application of this simple algorithm allowed also for partial, local decrease of rolling influence on bottom image. To obtain more satisfactory results, which could allow for total removing of rolling influence from entire image, more advanced algorithm, or combination of several correction algorithms is needed.

Conclusions

The geocorrection procedure was proposed and applied for the multibeam data describing the bottom relief. In the both cases of numerical examples, the obtained algorithm performance is acceptable in this stage of the investigation. The obtained results showed that the applied algorithm may be suitable for removing of local disturbances in multibeam bathymetric data due to errors, of relatively large spatial sizes. For instance, such distortion may be caused by the instrumentation errors of some kinds, or rolling effect during the acquisition process. In the latter case however, the algorithms using different and more advanced approaches might be used concurrently.

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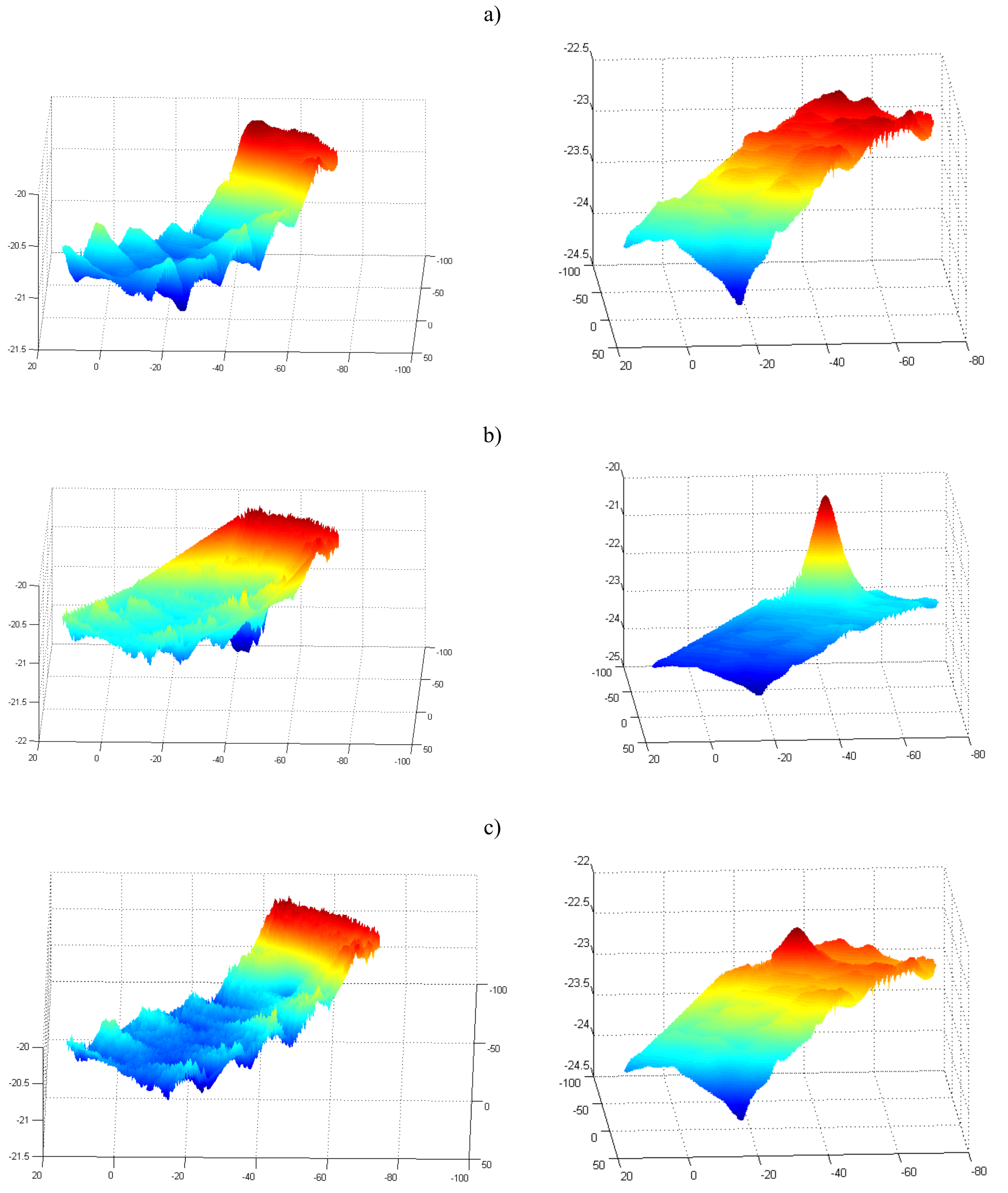

Figure 4 : Three successive stages of multibeam bathymetric data processing for testing of proposed geocorrection algorithm (left: case 1 – data with strong roll periodical error, right: case 2 – data without strong roll periodical error): a) multibeam sonar seafloor relief data after 2^D Kalman filtering, b) data from (a) after distortion added, c) seafloor relief data after gecorrection