1pAO7. Midwater acoustic modeling for multibeam sonar simulation.
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Abstract

Simulation and modeling software has been developed to generate synthetic midwater multibeam data. Essentially, the simulator can be considered as a virtual test tank. In order to develop multibeam data analysis methods for fisheries research, it is essential to have a variety of test data sets available, which are ground truthed, georeferenced and corrected for vessel motion. Since equipment and ship time are expensive and data quality not always guaranteed, the simulator provides an effective alternative. The seabed and any objects in the water column such as fish and fish schools can be defined in a 3-dimensional space. A specification for a generic linear array multibeam sonar and its position in space and time can be chosen. The acoustic model implements the technique of acoustic ray-tracing to obtain the pressure at the transducer face, which is converted to individual samples by modeling the working of a digital multibeam system. Beamforming is performed on the fly, and both raw and beamformed complex data sets are generated. Statistical validation of the generated data has been conducted successfully.

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Midwater acoustic modeling for multibeam sonar simulation

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Introduction

In recent years, multibeam echosounders capable of logging data for the full watercolumn have become available. Unlike bathymetric multibeam sonars, which only capture the seafloor, full watercolumn multibeam systems result in very large data sets and allow for visualization and analysis of objects other than the seabed as well. Currently, no standardized methods are available to extract useful information from those data sets quickly. Useful information includes geometric and acoustic descriptions of objects in the water, such as single fish, fish schools and the seabed.

Background

In researching multibeam data analysis techniques, well understood and ground truthed data sets are required in order to test and benchmark algorithms. The problem is that such data sets are not yet readily available, at least not where they contain a variety of fish schools with a wide range of different features. Therefore, a computational model that simulates the working of a multibeam system was developed. The model generates synthetic full watercolumn multibeam data that can be used in further research.

Modeling and simulation

There are three components that make up the multibeam simulator: the underwater environment, the multibeam sonar, and the acoustic model.

The underwater environment model is a description of a number of 3D objects in the water, such as the seabed and fish schools. The geometric properties of the objects must be defined, and also the density of schools, and a scattering coefficient for the seabed.

The model of the multibeam sonar used is a generic linear array. Various parameters can be specified, such as the length of the array, the number of transducer elements, its operating frequency, range, and ping and sampling rates. It is assumed that the sonar is mounted on a vessel, for which a cruise track can be defined.

Running the simulator involves modeling of the acoustics involved in transmitting a pulse, the pulse's propagation, and the scattering off the objects in the water. The model implemented is an acoustic ray tracer, tracing the paths of the pulse as it travels through the water. The sonar's sensors will sample the pressure at the sonar face at discrete points in time, resulting in what is commonly referred to as raw data.

This complex raw data is then beamformed, and the amplitude and phase components saved to disk, thus resulting in a synthetic multibeam data set.

Advantages of the simulator

Apart from providing a quick and easy way of generating multibeam data sets, the model has a number of additional advantages. It is for example very straightforward to vary one specific parameter in the model, re-run it, and compare the resulting data sets. In addition to that, various noise sources and levels can be introduced, and noiseless data can be compared with noisy data.

In investigating object detection and classification techniques, any combination of underwater objects with various features can now be created, and the corresponding data sets generated, something which is almost impossible to do in the real world.

Validation

If the synthetic data sets are going to be used for algorithm design, it must be verified that the synthetic data is representative of real data; that is, it must exhibit the same characteristics. From scattering theory, raw amplitude data is expected to be K-distributed. This hypothesis was tested using the chi-square test, on the basis of which the hypothesis could not be rejected. Initial investigations show that the synthetic data has the same probability distribution as real data. Further studies are being conducted.

Future work

Apart from investigating multibeam data analysis techniques, enhancements to the model may be introduced, such as including sound speed profiles rather than assuming a constant sound speed, including better models of fish schools and fish behaviour, and more accurate scattering models. Also further comparisons with real world data will be conducted.

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