Real-time reverberation modelling for ASW active-sonar operator training

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Abstract — For the training of operators of a Low-Frequency Active Sonar (LFAS), the need arose for a simulation capability that produces realistic sonar data to reflect the complexity of shallow water LFAS data. Simulated sonar data should not only contain targets and noise, but also reverberation that is expected when operating in shallow water, where upslope and downslope effects influence detectability and consequently affect tactics. The BISON bistatic sonar model simulates the levels of received acoustic intensity arising from surface and seabed reverberation for any source-receiver combination and can be applied to dipping sonar or towed line-array receivers. Using ocean bathymetry maps, details such as enhanced and decreased scattering from up- and down-sloping seabeds can be simulated. Due to the modular approach of BISON, this model can also be extended to other information in atlas-form, such as pipelines, shipwrecks and other forms of geoclutter. The simulator runs in real-time and has been implemented in the operator-training facility of the Royal Netherlands Navy.

1 Introduction

The capability of simulating realistic sonar data in real-time is a valuable aid in the training of sonar operators. The more realistic the simulated data are, the more operators can be trained to cope with the complexity of sonar data in different environments. Training can be done with actual sonar data recorded at sea but such data are static and do not allow the trainer to change the training objective. A static training also does not allow the trainee to investigate the impact of changing sonar settings. If a simulator can produce sonar data in real-time, both the trainer and trainee can interact with the simulation and enhance training effectiveness.

A low frequency active and passive sonar (LFAPS) simulator for anti-submarine warfare (ASW) operator training, called SimSon, has been developed. The simulator produces data at hydrophone level and features the propagation and doppler of target echo and passive sonar data. Environmental effects, such as ambient noise are also included to enhance realism. In shallow water scenarios reverberation becomes an important effect. To model this effect, the BISON sonar model is used.

BISON has been developed for situations where ocean-environmental conditions are described to an ‘atlas level of detail’. Often, information of the bathymetry and average water-column properties are available, but seabed reflection/scattering properties are not. In such cases the accuracy of the acoustic predictions is more likely limited by input information uncertainty, rather than mathematical model precision. Consequently, a simple model with a sound, physical basis likely performs as well as a more complicated and mathematically rigorous approach in predicting realistic sonar data. The simpler method will also have lower computational costs in terms of run-time and memory, and fit our purpose of a real-time training tool.

2 Approach

BISON uses bathymetry maps to generate reverberation data. Seabed reverberation is calculated with Lambert’s rule [1], modified with local slope:

\[ I_r = \frac{1}{r} \mu A \sin(\theta_i + \delta_i) \sin(\theta_r + \delta_r). \]  

(1)

where \( I \) and \( I_r \) are the incident and scattering intensity, \( \mu \) is a scattering strength (determined by the seabed type), \( A \) is the area of the scatterer and \( \theta_i \) and \( \theta_r \) are the propagation angles (measured relative to the horizontal) of the incident and scattered rays. The \( \delta_i \) and \( \delta_r \) terms are the local seabed slope, resolved in the vertical planes containing the source and receiver respectively. The addition of local slopes leads to enhanced and decreased scattering from up- and down-slopes.

Surface scattering is calculated with Chapman-Harris’ empirical formula [2], modified to the bistatic case:

\[ I_r = I_0 Ab \left( \frac{\theta_{deg}}{30} \right)^a \left( \frac{\theta_r}{30} \right)^b, \]  

(2)

where \( a \) and \( b \) are functions of frequency and windspeed:

\[ a = \frac{26.1}{(w_{kt} f_{Hz})^{0.2}}, \]  

(3)

\[ b = 8.66 \times 10^{-1.8} (w_{kt} f_{Hz})^{0.82}. \]  

(4)

Thirdly, all paths from source to scatterer to receiver are calculated and form a list of arrivals (intensities, travel times and bearing). Propagation loss is applied, after which intensities falling in the same time-bearing bin are summed.

Fourthly, bathymetry maps are used to mask areas where the line of sight from source to scatterer to receiver is blocked by very shallow water or land.
The simulated seabed reverberation is diffuse and random in nature and produce a fog that can hide target echoes. Discrete features such as rock outcrops and shipwrecks can result in sharp echoes and trigger false alarms. These ‘geoclutter’ points are also simulated as they are important sources for false detections in real sonar data. Thus, as a final step, geoclutter points are calculated from upslope regions and given enhanced target strength.

3 Results and discussion

Figure 1 shows a simulation result. The left part shows SimSon output in which the trainer can construct training scenarios. In this case, a track of the own ship with towed sonar is shown heading north. At the time of the picture, the ship is at two-thirds of the track. The trainer can modify environmental settings, add or change targets in real time, or change course, amongst other things. The bathymetry map is shown in the background. The right part shows a range bearing display with simulated reverberation data.

4 Conclusions

Robust, physics-based modelling has been shown to be capable of producing predictions of seabed reverberation that are realistic enough to be included in sonar-operator training software and run in real time. The resulting simulated data allow operators to be trained with realistic simulations while retaining flexibility for trainers to adapt scenario settings and for the consequences of these changes to be modelled in real-time.

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References


Author/Speaker Biographies

Kai Yan Eugene Leung graduated with a Master's degree in Applied Physics at the Delft University of Technology. Since 2015, he is a scientist and software engineer in the department of Acoustics & Sonar at the Netherlands organisation for applied research (TNO).