Environmentally Adaptive Sonar Technology

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LONG TERM GOALS

The goal of the ONR Environmentally Adaptive Sonar Technology (EAST) program is to develop the technology base for an automated, environmentally adaptive sonar system.

OBJECTIVES

Develop and demonstrate technologies that: (1) improve characterization of the environment by extracting important environmental acoustic parameters from combatant sonar data; (2) merge environmental parameters into a shared, dynamic, real-time databank suitable to the demands of littoral undersea warfare; and (3) automate environmentally adaptive sonar control.

APPROACH

Our technical approach is aimed at two basic problems with undersea warfare: (1) knowing the environment, and (2) adapting the sensor to the environment to maximize sensor performance. A consequence of (1) in this approach is that the knowledge of the environment, along with accurate sensor performance models, provides more accurate feedback to an operator about current sensor performance, a requirement for successful automation in (2).

We are developing two technologies for knowing the environment: (1) extracting key environmental parameters from combatant sonar data, and (2) merging the extracted parameters into a shared, dynamic, real-time databank. While a number of approaches have been developed for parameter extraction from combatant sonar data, we have focused on extracting surface and bottom reflection losses and backscatter from active sonar in range dependent environments because: (1) current sonar programs have focused on active sonar to counter the quiet diesel submarine, and (2) there is a lack of bottom backscatter and bottom loss information that is key to understanding sonar performance in the littorals. Our Sonar Environmental Parameters Estimation System (SEPES) uses acoustic path information, including arrival time, source and receive angles, and propagation loss, to reduce the complex shallow water reverberation time series into a decomposition of boundary losses and scattering versus bottom parameters (e.g., grazing angles or geoacoustic parameters). We use a nonlinear optimizer to automatically adjust acoustic model parameters until the measured reverberation is reproduced, thereby “auto-calibrating” the model to the measured reverberation data. Extracting basic acoustic parameters from the reverberation data allows for optimizing sonar control based on different sonar control parameters, such as changing sonar depth, that can’t be accurately produced with measured reverberation alone. Extraction of basic acoustic parameters also provides for consistency between the reverberation and estimates of target echo level, which is crucial to the signal excess calculations used to optimize sensors.

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We have been developing an object-oriented, dynamic, real-time environmental parameters databank (EPDB) that will store environmental data of different types in a flexible software toolset. The databank can hold a number of different data types including gridded data, point data, track data, and non-gridded triangulated mesh structures that provide increased resolution in areas of interest. The mesh is constructed as a series of data objects, linked through geo-registered coordinates, that can accept new data at any time. Our plans include quality checking of the data as it is added and distributing (extrapolating or interpolating) changes to other data points, if warranted.

Automated sonar control requires new approaches from disciplines that have had success in feedback control. There has been significant commercial success in a new field termed, “Computationally Intelligent Applications,” which applies a mixture of modern control techniques, such as fuzzy logic control, neural nets, and genetic algorithms, to solve complex control problems. Our paradigm is derived from successful commercial applications in electrical power system security assessment. In security assessment the electrical power distribution over the west coast can be predicted by a computationally intensive model (similar in complexity to an acoustic model), but the response time required to manage and safeguard delivery of the power precludes the use of the model in real-time monitoring of the system. Rather, a neural net controller was trained to mimic the model, and the neural net accurately reproduces the power distribution in real time. We are applying similar techniques to automate feedback control of a real-time sonar system that maximizes the sonar performance to changing environmental conditions.

WORK COMPLETED

Our work this year focused on extending the SEPES user interface and optimization components to handle range-dependent problems. SEPES now allows the user to specify up to five different bottom regimes in an optimization problem. The extensions have been tested using a reverberation calculation that considers range-dependent bottom effects, but does not yet include other range dependent effects, such as bottom depth and sound speed variations. Adding the additional regime information to SEPES made the old displays overly complex, so we improved the user interface by dividing the measured reverberation displays, and the surface/bottom losses and backscatter displays, into separate windows. SEPES is now ready for integration with CASS/GRAB, which will provide a full range-dependent capability.

This year we discussed software integration with Dr. Henry Weinberg, the author of CASS/GRAB, to come up with an interface design. We arrived at the fundamental design decision to have CASS provide the partial derivative information SEPES requires for optimization. (SEPES currently calculates this information internally.) This approach will improve system maintainability in the future, and requires fairly straightforward initial modifications to CASS. We are somewhat concerned about the extra computation required to provide derivatives in an iterative optimization, but expect that the CASS algorithms can be specialized to meet the SEPES information requirements in a timely manner.

This SEPES project is tied to a separately funded ONR project to develop new methods of automated sonar control using computationally intelligent control techniques (e.g., fuzzy logic and neural nets) and knowledge of the environment. SEPES provides "auto-calibration" of the sonar control model to a changing environment. The model provides performance feedback to the sonar system controller.

TECHNICAL RESULTS

Current environmental characterization techniques use distributed sources and receivers in monostatic and bistatic configurations. While this approach requires considerable resources, it does provide both transmission loss and reverberation measurements for the same environment. One way to verify that SEPES is accurately extracting parameters is to extract bottom loss estimates from measured reverberation, use those bottom loss values to model transmission loss, and compare the model results to measured transmission loss. APL-UW performed such a comparison using reverberation and transmission loss measurements taken in LWAD 98-2. The LWAD comparison shows good agreement. Further, the SEPES estimates of bottom backscatter strength are consistent with the levels from the APL-UW bottom backscatter model that used an NRL geoacoustic characterization of the bottom and measurements of surficial sediments. Therefore, we believe that our estimation technique shows considerable promise.

Results using a neural network to optimize sonar performance are also promising. In this work, we trained a perceptron-based neural net to reproduce sonar signal excess versus range and depth. We used a high-fidelity, range-independent acoustic model to train the neural net to reproduce signal excess over a range of sound speed profiles, wind speeds, and bottom types. Although it took 48 hours of computer time to model the environments, and 12 hours to train the neural net, it only requires milliseconds to reproduce a signal excess map. The neural net allows us to quickly invert the problem to compute the sonar control parameter values that maximize signal excess in a specific range-depth cell. Initial testing has proven that the process works well for computing optimum sonar depth.

These two components will provide a significant advance in automatic optimal sonar control. Our goal is to extract the environmental conditions (e.g., determined from SEPES on a ping-per-ping basis), use those environmental parameters to initialize the neural network, and invert the neural net to compute the optimal sonar control parameter values.

SYSTEMS APPLICATIONS

Our environmental adaptive sonar control techniques are being considered for use in three major system developments. The new Integrated Undersea Warfare for the 21st century (IUSW-21) program is conducting major risk reduction for the USW segment of the new land attack destroyer (DD-21). Our concepts have been included in a major Advanced Technology Demonstration (ATD) proposal that was presented at the final FY00 ATD review and received strong endorsements from N863, PMA 299 and the Oceanographer of the Navy (N096) for demonstration with an AN/SQQ-89 surface ship combat system, the new multi-mission helicopter (SH-60R), and the N096 Battlespace METOC Data Acquisition, Assimilation, and Application (BMDA3) system. While the ATD proposal was not funded the development of these concepts will meet critical requirements of the above acquisition efforts.

TRANSITIONS

The above mentioned programs have transition potential and, the Program Executive Office for Air ASW, PEO(A), has programmed funding to start in FY02 through PMA-264 for a new Tactical Air Mission Decision Aid (TAMDA) that will develop a new environmental buoy and an aircraft-based, onboard, tactical decision aid. The techniques developed here are being currently used at NAWCAD-PAX in the initial development and analysis process with the intent of incorporating EAST algorithms in TAMDA. N096 is expected to provide FY99 6.4 funding for initial evaluation of the SEPES algorithms for the environmental buoy.

RELATED PROJECTS

We have a joint project with the Computational Intelligent Applications Laboratory (Professor Bob Marks and Mohamed El-Sharkawi) Department of Electrical Engineering, University of Washington to develop new techniques in automated environmentally adaptive sonar control. This ONR/ARL sponsored effort, "Environmentally Adaptive Sonar Controllers," is directly linked with our EAST efforts and uses the algorithms developed to invert the bottom properties to provide in-situ acoustic feedback for improved sonar performance. The techniques developed in that project are to be transitioned to this EAST program for further development and demonstration. Another APL-UW project is with Dr. Robert Odom for Eddie Estalote of ONR, "Bottom Backscatter/Loss Models: Inversion and Databases." The objectives of that work are to: (1) develop a data-verified, OAML-approved bottom backscatter/bottom loss model with consistent physics from 100 Hz to 100kHZ; and (2) work with NAVOCEANO to construct a world-wide bottom backscattering strength database to aid in accurate performance prediction for ASW active sonar systems. SEPES will eventually extract parameters suitable for this bottom backscatter model. This backscatter model is being adapted as the Navy standard backscatter model. Project I2, Environmental Adaptability, is also closely related.

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PATENTS

None.