An Environment Modeling Manager for Tactical Decision Aid Support

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***Abstract**: Over the past several years Defence R&D Canada – Atlantic has been building a flexible system to provide ocean acoustic predictions to a wide variety of consumers. Called the Environment Modeling Manager (EMM), this system utilizes a client/server paradigm where various tactical decision aids, combat system algorithms, and sonar operators can register for specific acoustic information. The results are then provided on either a once-only or periodic update basis. Based on the CORBA standard, a server satisfies the requests of registered clients by running one or more ocean acoustic prediction models, such as Bellhop or the Allied Environmental Support System. Alternatively, certain prediction data might be based on through-the-sensor measurement. Important but compute-intensive processing, such as the signal excess over an area of ocean, can be scheduled to run during idle time or on a dedicated prediction engine, allowing a client request to be immediately satisfied with the latest update.*

1. Introduction

The prediction of the ocean environment is an increasingly important component of naval Underwater Warfare (UWW) as subsurface platforms become progressively harder to detect and localize. Modern acoustic sensor tracking algorithms and tactical decision aids rely on a representation of the underwater environment to improve sensitivity and accuracy. This in turn has required increasingly accurate predictions of the ocean acoustic field in order to estimate expected signal characteristics at the sensor. Current systems normally assist an acoustics operator via manual entry and screen display, with little connection to external systems. In turn, tactical decision aids often have dedicated prediction engines that lead to inconsistent results across the differing applications. With these issues in mind, Defence R&D Canada – Atlantic began developing a concept demonstration package to show how a flexible acoustic prediction system could meet the evolving needs of the Navy and the lab's oceanographic projects. Called the Environment Modeling Manager [1,2], or EMM, the new system is designed about a client/server paradigm that allows multiple clients to access a number of prediction engines and to be supplied with updated information as it becomes available. These clients can reside on different computing platforms running disparate operating systems, and the software can be written in the language most suitable to the application. Representative client programs include tactical decision aids (TDA), combat system algorithms, and operator requests. These clients are assured of consistent results since the environmental and prediction information is obtained from a single source.

Recently EMM has been integrated into the Networked Underwater Warfare Technology Demonstration Project (NUW TDP) [3,4], which will demonstrate concepts in networked-enabled UWW. This project is investigating the sharing of refined sensor information over an RF network, including issues with data quantity, queuing based on the phase of the operation, prioritization, and the resulting impact on target tracking and localization. A sea trial will highlight multiplatform cooperative operations against an underwater target, with a Canadian CP140 maritime patrol aircraft supplying sonobuoy information to the Canadian Forces Auxiliary Vessel QUEST. The ship will be towing an operational towed array and processing both passive and low frequency active data. Localization of the target will involve fusing feature data from the sonobuoy field with that from the towed array, while utilizing radar to discriminate against surface traffic. The Environment Modeling

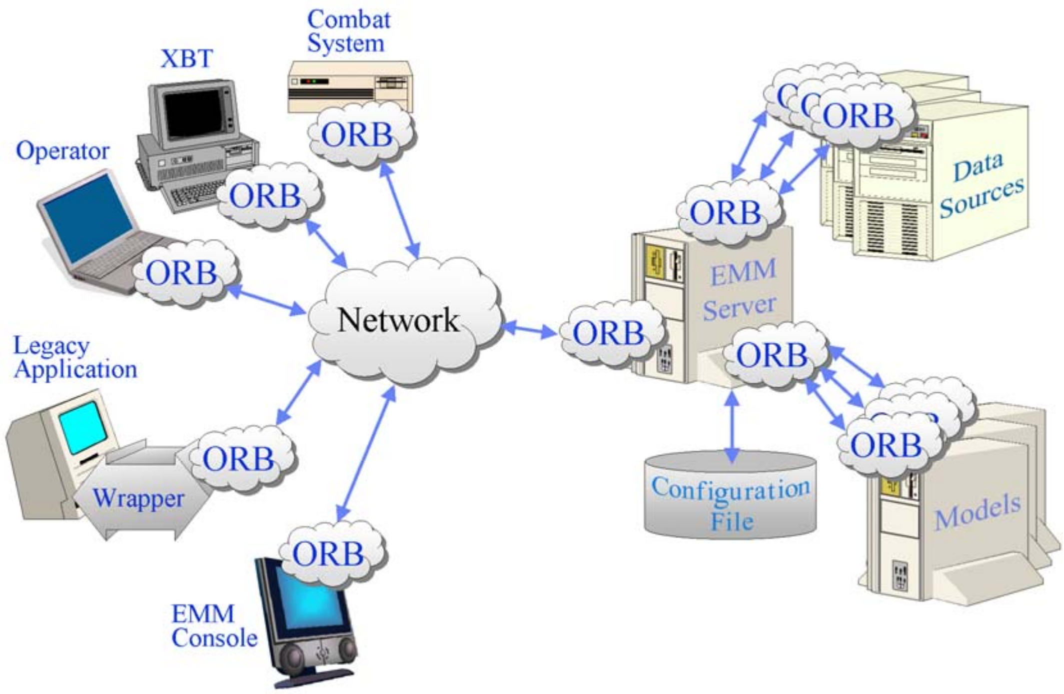

Figure 1: Framework of EMM, showing the client/server architecture.

Manager will provide acoustic predictions for both pre-trial planning and for combat system applications, such as passive localization, data fusion, and operator displays.

This paper introduces the EMM system that controls acoustic prediction engines, provides an overview of the framework used to implement EMM, and describes the capabilities of the system. It concludes with a look toward future directions and applications. There will be only passing reference to the acoustic models and their supporting data sources.

2. Framework

The Environment Modeling Manager has been implemented using an open architecture approach. This allows the system to employ non-proprietary, standards-based components wherever possible and thus minimize any dependence on specific hardware or software. The core of the architecture is the Common Object Request Broker Architecture, or CORBA, that provides a standardized method of communication between distributed objects, supplying a common mechanism for objects to access each other's state and functionality through exported interfaces. The Object Request Broker (ORB) establishes the client/server relationship between software objects. Since all communication between processes occurs through both the ORB and standardized client/server interfaces, there is total programming language, operating system, and network independence. With the ORB handling the client's requests for services, neither the client nor the server requires any knowledge of the other's physical location on the network. Relocation of either client or server to another machine, perhaps for load balancing, does not impact the system. Client applications simply register with the server ORB for specific services. This system can accommodate legacy applications by having a small wrapper translate the old program's input/output requirements to that understood by the ORB.

An overview of the EMM infrastructure is shown in Figure 1. The EMM Server is the central hub of the distributed client/server system. The system is designed to be flexible, with any number and variation of heterogeneous models, data sources, and clients connected at a given time. The server processes an XML configuration file that specifies default values for most of the system parameters

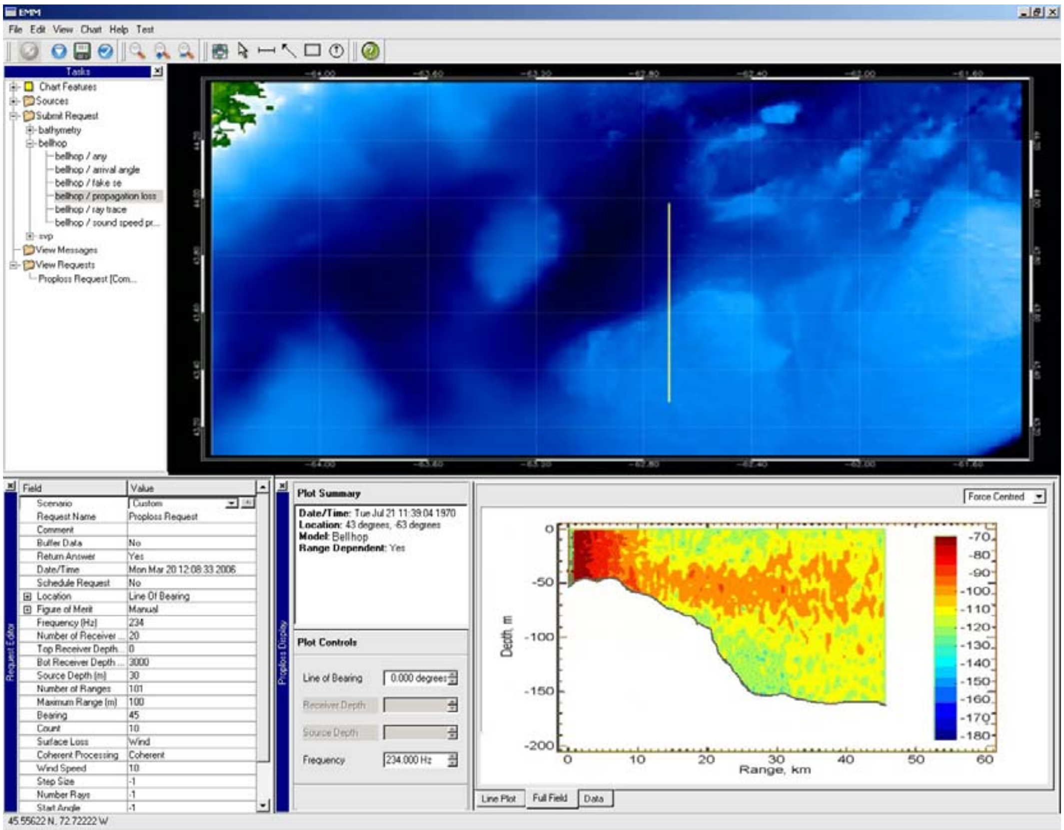

Figure 2: Screen capture of the EMM Console, showing a full field transmission loss plot along a line-of-bearing looking due north.

and client request fields. When a client connects to the server, the server responds with a list of the available acoustic prediction models and data sources. The server also provides the appropriate default values for each model and data type. Examples of the default parameters include such items as current sensor location, pre-calculated range of the day, and sensor depth. Over time the default values can be updated to reflect the latest conditions. The system hosts a number of back-end sources of data that appear as clients to the EMM server. These modules provide information needed by an acoustic prediction engine, such as a sound speed profile, absorption and scattering from the bottom and surface, or bathymetry.

The main controlling program is the EMM Console, which handles configuration, health monitoring, and manual entry duties. The Console monitors the server's supporting applications to ensure the health of the system. Modules that have crashed can be restarted or the operator alerted for further action. The embedded Display Client provides the default GUI interface for operator requests. It lists the prediction engines and data sources connected to the EMM server, marshals and sends the requests to the server, and displays the returned results as graphs, overlays, or tabular data. When multiple sets of results are returned the operator can view these via a tabbed system. Figure 2 illustrates the layout of the Console. The panel in the top left corner shows the list of available sources and models. The chart indicates the bottom topography overlaid with icons indicating the locations of model solutions. The list of input variables for a prediction request is located in the lower left, and the results and plotting parameters are subsequently displayed in the panel at the lower right.

3. Capabilities

The EMM system incorporates a number of features to provide speed and accuracy. The server is designed to accommodate any number of prediction engines to handle the processing. Consequently,

Table 1: Non-exhaustive list of current and future products available to client applications. An empty location indicates not applicable, and *I* indicates interpolated from the radial calculation.

Request Type	Single Point	Line of Bearing	Radial	Grid
Bathymetry	Y	Y	Y	Y
MGS bottom loss	Y	Y	Y	Y
BLUG bottom loss	Y	Y	Y	Y
Sediment	Y	Y	Y	Y
Wind	Y	Y	Y	Y
VSS	Y	Y	Y	Y
Sound Speed Profile	Y	Y	Y	Y
Propagation loss	Y	Y	Y	I
Raytrace		Y	Y	I
Reverberation	Y	Y	Y	I
Eigenrays	Y	Y	Y	I
Figure Of Merit	Y			
Signal Excess	Y	Y	Y	I

there can be a mix of acoustic models to provide optimal predictions over the full range of frequency and ocean parameters expected to be encountered during a mission. This mix could include models to handle passive acoustics as well as others specialized in active sonar prediction. The design also allows multiple copies of a particular model to maintain throughput on compute-intensive applications, such as active sonar reverberation, and to handle numerous client requests. This permits improved response times by paralleling requests that involve many prediction calls. For instance, the calculation of transmission loss over a set of bearing lines radiating from the sensor could be farmed out to different engines, each handling a sub-set of the specified lines-of-bearing. In a similar manner EMM handles the data sources as just another set of clients. Thus, a more refined database of historical sound speed profile, or a higher resolution bathymetry file, can be swapped in without significantly impacting the system. The new data source is subsequently available to all the prediction engines.

Registration of client programs provides a powerful method for managing the communication between applications and the EMM server. Clients submit requests for specific ocean environment information, and the data is automatically pushed back without further intervention. The data is also buffered for use by other programs that have registered for this information. In addition, clients can request a list of the buffered data and so discover what is immediately available. A sample list of the information available from the Environment Modeling Manager is indicated in Table 1. The possibility of numerous applications registered with EMM demanded a framework capable of handling simultaneous requests. The implemented solution involves a queuing system that serializes the requests and allows throttling if the prediction engines become overwhelmed. A future enhancement might include prioritization of the elements in the queue based on the phase of the tactical operation or other factors.

Many of the prediction solutions grow stale over time, as the platforms move and environmental conditions change. The EMM employs a scheduling system to provide re-calculated solutions at regular intervals. Any client program can initiate a scheduled prediction request, and a future version will have the updated solution published to all clients who have registered for it.

The Environment Modeling Manager provides a layer of capability to relieve client programs from having to make numerous requests. Applications can request prediction estimates at a single geographic point, along a line-of-bearing, and over a region. The region can be subdivided into a set of bearing lines radiating from a geographic location (radials), or a regular grid of positions. Internally, the solutions at grid points are often obtained by interpolating from calculations along radials.

4. Acoustic Prediction Engines

The current ocean acoustic prediction system for the Canadian Navy is the Allied Environmental Support System (C-AESS), which is mainly a manual entry and display program. The operator must input a substantial quantity of data via a series of screen windows, and how the results are viewed depends on the configuration of the vessel. C-AESS may be treated as stand-alone or it may be part of the network to allow dissemination of the results. The system supports a number of acoustic models that are viable only within specific frequency and ocean environment regimes. Consequently, there must be significant knowledge of the various model limitations in order to obtain viable solutions. Operators must also have a deep working knowledge of C-AESS, since the plethora of functions makes it difficult to correctly configure the models and extract the acoustic predictions. As it is an operational system and there is little access to the source code, the ability to enhance the functionality or to repair coding errors is very limited. Two further impediments for R&D use result from the computer code and databases being classified, and the necessity to host it on outdated hardware and operating system.

Some of these problems were circumvented by directly accessing C-AESS's prediction engine and environment databases within EMM. During testing, it was discovered that certain modules would quietly crash if the number of requests exceeded a certain rate. Throttling of the requests was implemented but careful tuning was still needed to prevent catastrophic failure of the engine. In addition, the version of C-AESS used in Canada had little capability for delivering predictions for active sonars. This led DRDC Atlantic to consider alternate engines. The program called Bellhop [5,6] was chosen for further development and enhancement, largely because it is open source, handles range dependence, and is relatively efficient. Some of the functionality being added includes 1) reducing the number of model options for easier use in an operator environment (as opposed to full flexibility for scientific research) [7]; 2) determining bottom loss and scattering using measured bottom parameters rather than the traditional BLUG[1] and MGS[2] provinces; 3) making intermediate values, such as vertical arrival angle and the amplitude/phase of each ray, accessible to client applications; and, 4) adding reverberation prediction for active sonars. Alternate data sources, such as historical sound speed profiles and high resolution bathymetry, are being added to replace those originally accessible through C-AESS.

5. Applications

The primary focus of the Environment Modeling Manager is to provide the prediction capability for the NUW TDP. Copies on both the surface ship and the maritime patrol aircraft will share environmental data and configuration parameters to ensure consistent acoustic modeling on all cooperating platforms. A Reach-Back cell at DRDC Atlantic will provide further processing capability and access to additional environmental data. Besides for preplanning, EMM will be used to predict ocean conditions to improve the accuracy of the project's combat system data fusion and localization algorithms.

Another project considering EMM is the lab's Ship Signature Management System [8], which is designed to aid the naval noise control team in real-time monitoring of their self-signature. The system will provide counter-detection ranges and predict the consequence of changing the ship's running configuration. Utilizing hull-mounted accelerometers, local bathymetry, and periodically measured sound speed profiles, EMM would continuously predict detection ranges to hostile vessel sensors and alert ship's staff to significant events. An example is shown in Figure 3, where a polar plot indicates the likely detection range at different frequencies. With EMM's ability to add new models and data sources, the system could be configured to also identify the causes of features in the

[1] Bottom Loss UpGrade. Values between 1 and 9 represent different levels of bottom loss.
[2] Marine Geophysical Survey. Similar to BLUG but used to estimate bottom loss at higher frequencies.

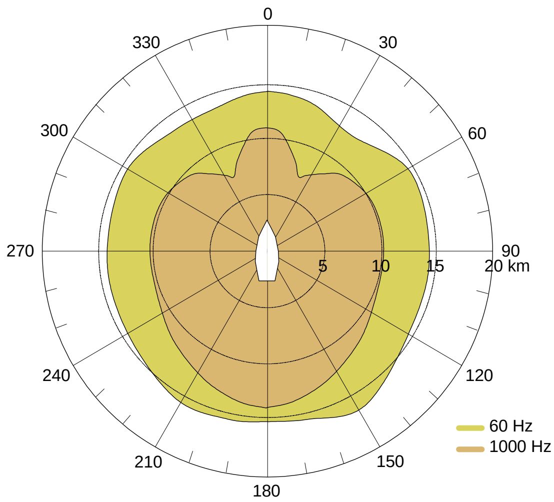

Figure 3: A cartoon illustrating expected counter-detection ranges using hull-mounted accelerometers and signal excess predictions.

radiated spectrum, predict the consequence of changing the machinery configuration, and monitor the overall acoustic health of a platform.

Simulation and modeling is another area where the Environment Modeling Manager could add capability. With its flexibility and ease of connection to outside applications, EMM could provide the response of virtual undersea sensors in sophisticated maritime war gaming simulations. DRDC Atlantic has been investigating the improvements and issues resulting from multi-platform networked-enabled operations through large-scale simulations [9] based on the Virtual Maritime Systems Architecture (VMSA) [10]. Currently, the underwater acoustic environment is modeled through simplistic spherical and cylindrical spreading formulae. The project is actively investigating such possible prediction solutions as EMM to significantly improve fidelity and incorporate a range-dependent character to the scenarios.

6. Future Directions

There remain a number of enhancements on the wish list. The higher priority improvements include the following:

- When C-AESS is not present, data sources that hold ocean parameters such as sound speed profiles are largely in a flat-file format,. There is a need to upgrade to spatially-enabled databases to allow tighter coupling between the models and measurements at specific chart positions.
- With the increasing use of low frequency active sonars, EMM must incorporate models that can predict acoustic conditions during LFA operations. The plan is to add this capability into the Bellhop model.
- The framework allows multiple instances of a particular prediction engine, or a mix of models. With indications that the NUW combat system may require a higher throughput rate, a number of instances of Bellhop may need to be implemented to ensure adequate response times.
- One component of the NUW concept demonstration is through-the-sensor measurement of the acoustic environment to increase the fidelity of model predictions. Such measurements would form part of the set of data sources accessible to the acoustic models and other clients. As an example, through-the-sensor estimates of the ambient noise field would improve the accuracy of passive signal excess and figure of merit (FOM) predictions, and measurement of reverberation would improve active sonar solutions.
- The current chart display in the EMM Console needs replacement with a system able to handle a number of layers of information. The plan is to integrate the chart functionality from the Common

Operating Environment (COE) into the EMM Console for stand-alone use. When the NUW research-level combat system is a client, information from EMM can appear as another set of layers on the combat system's COE chart. Along with detected targets and other sensor/track information, predictions such as the expected signal excess from a target over a region might be displayed. These layers could be turned on and off to allow an operator to drill down through the data.

- In the longer term, automatic determination of the optimal prediction algorithms based on the current operational conditions and measurements would improve the user-friendliness and overall accuracy of the returned information.

7. Summary

The Environment Modeling Manager provides a robust and flexible means to distribute acoustic prediction information to a disparate group of applications. Based on a client/server framework and using open-source middleware, EMM accepts the registration by clients for specific predictions, manages the model engines to generate the solutions, and returns the results to the appropriate clients. Client applications can specify a periodic update schedule for solutions that are prone to becoming stale from changing water conditions and/or location. The number and mix of engines can be adjusted to match the requirements of the requesting applications, and the various data sources can be swapped as needed. The capabilities of the Environment Modeling Manager concept demonstrator are designed to show how a flexible acoustic prediction system can meet the evolving needs of the Navy and the lab's oceanographic projects.

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