EOID Model Validation and Performance Prediction

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LONG-TERM GOALS

Our long-term goal is to accurately predict the capability of the current generation of laser-based underwater imaging sensors to perform Electro-Optic Identification (EOID) against relevant targets in a variety of realistic environmental conditions. The two most prominent technologies in this area are Laser Line Scan (LLS) and Streak Tube Imaging Lidar (STIL). Examples of systems using these technologies are the AN/AQS-14 (using LLS) and AN/AQS-20/X (using STIL) mine-hunting systems.

OBJECTIVES

Our objectives are to develop and validate EOID models and metrics for image synthesis and prediction of operator identification. When these models are developed, they will be incorporated into prototype tactical decision aids.

APPROACH

We have modified the Metron EODES software to represent LLS and STIL in terms of a set of parameters for each system. For either type of system, the choice of values for the parameters is based on those of existing systems. Sensor data collected during August 2001 field test from Areté, Raytheon and Northrop Grumman systems will serve to validate our models.

Statistical models of the ocean optical environment and system operating conditions were developed in order to represent the uncertainty in the model inputs for validation. This is needed in order to estimate the uncertainty associated with the validated model outputs.

The validation categories selected with these goals in mind is given in Table 1. The left column of the table describes the quantities that are compared between model and data, the right column describes the issue that the validation addresses.

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14. ABSTRACT
Our long-term goal is to accurately predict the capability of the current generation of laser-based underwater imaging sensors to perform Electro-Optic Identification (EOID) against relevant targets in a variety of realistic environmental conditions. The two most prominent technologies in this area are Laser Line Scan (LLS) and Streak Tube Imaging Lidar (STIL). Examples of systems using these technologies are the AN/AQS-14 (using LLS) and AN/AQS-20/X (using STIL) mine-hunting systems.

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Table 1. Categories for sensor-model validation.

Pure radiometry (mean signal levels)	Does the model predict mean photon levels correctly?
Stochastic noise processes	Does the model represent random receiver and environmental noise processes correctly?
Modulation Transfer Function	Does the model represent the mean blurring effect of the ocean environment correctly?
Forward-scatter and back-scatter noise	Are volume backscatter processes correctly represented?
Range resolution and 3-D Edge response	Are range dependent blurring processes well-represented by the model?

WORK COMPLETED

To date we have developed radiometric calibrations for the Raytheon, Northrop Grumman, and Areté systems. Using field data from regions of constant reflectance, the Pure Radiometry validation appears to indicate an offset between the measured and predicted levels of a factor of between 1.2 and 2.0, depending on the system. These preliminary results appear to be consistent across the data sets, indicating that there may be engineering parameters (such as transmission losses within the optical train) that are not accounted for in the model. This level of offset is important mainly in the photon noise-limited operating conditions, and will be addressed in follow on work.

The environmental measurements from the test data have been converted into a set of probability models that can be used to synthesize realizations of the ocean optical parameters. This enables us to quantify the uncertainty in the model validation results using the Monte Carlo method.

Finally, the results of the Target Acquisition Method testing has yielded estimates of the human operator ID capability as a function of image transfer quantities.

RESULTS

The sensor model is capable of performing calculations that are essential inputs to quantifying STIL and LLS system performance. The model uses a detailed impulse response function model for each system. The impulse response function estimate accounts for both the multiple scattering environment and the sensor sampling method.

A statistical model for estimating environmental optical properties and their uncertainties in time and space from a few discrete measurements has been developed. Figure 1 shows a comparison between a measured parameter and one simulated using an autoregressive moving average model of the autocorrelation structure in depth.

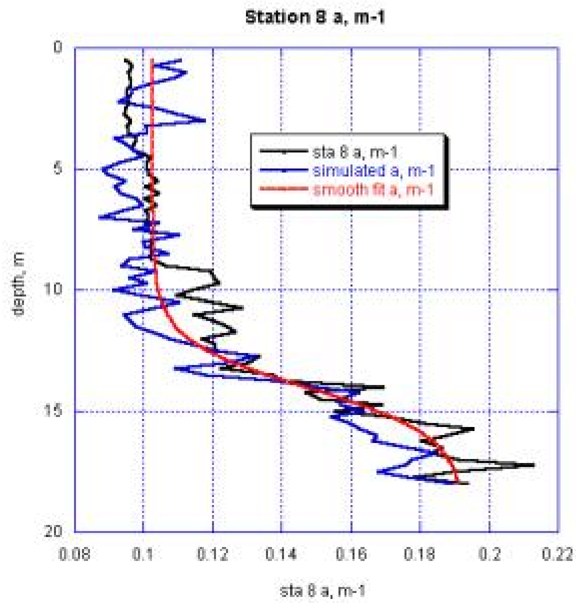

Figure 1. Model of inherent optical property profile as an autoregressive moving-average process in depth. The black line is original data, the red line is the mean function of depth, and the blue line is a simulated profile with the same autocorrelation function over depth. The variability and correlation structure of the simulated series is similar to the data in the deep layers.

A model of the human operator's ability to identify targets subjected to controlled amounts of blurring and noise was developed using trained operators who viewed synthetic target and clutter images and made identification calls. The blurring and noise quantities were reduced to a single function of the number of resolvable bars in the image, N. The probability of identification as a function of the metric N is shown in Figure 2.

IMPACT/APPLICATION

When completed, this work will support the completion of a validated Laser Line Scan and STIL EOID performance model for distribution. This work will also result in the development of a prototype EOID tactical decision aid.

TRANSITIONS

The models and metrics developed and validated by this work will be transitioned into tactical decision aids for the AN/AQS-14A(V)1 and the AN/AQS-20A.

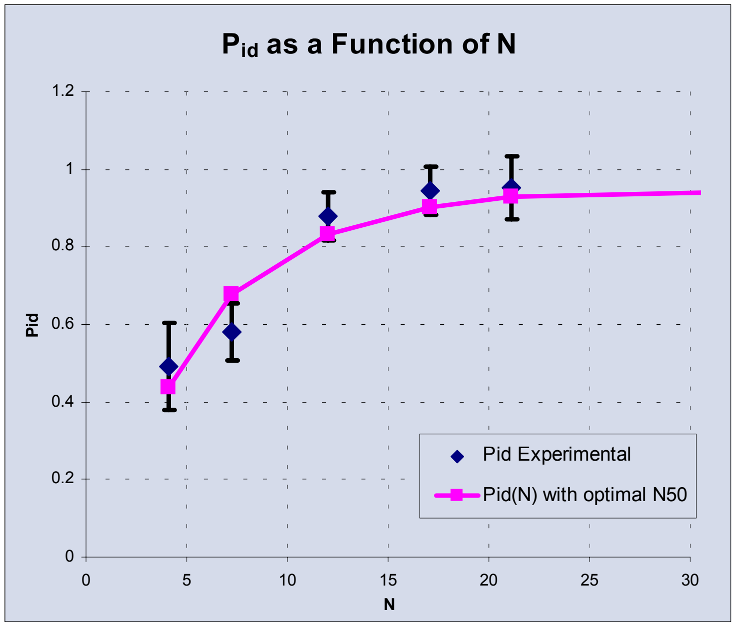

Figure 2. Graph of the probability of operator identification of blurred and noisy images as a function of the number of resolved bars over the target (N). The probability of identification rises from about 0.4 at N of 4, asymptotically to 0.95 at N of 20.

RELATED PROJECTS

Airborne Laser Mine Detection System (ALMDS).

Rapid Airborne Mine Clearance System (RAMICS)

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