Electro-Optic Identification (EOID) Research Program

Gene M. Cumm
Northrop Grumman Oceanic and Naval Systems
P.O. Box 1488
Annapolis, Maryland 21404
Phone: (410) 260-5988 fax: (410) 260-5950 email: Gene_M_Cumm@md.northgrum.com

Award Number: N0001401C0010

LONG-TERM GOALS

The goal of this research is to provide EOID sensor data from two two-week data collection efforts to be used for Laser Line Scan (LLS) sensor model validation. In addition, this data will also be used for algorithm generation and verification for an Automatic Target Recognition (ATR) effort.

OBJECTIVES

To collect data under a wide range of operating and environmental conditions and develop precise algorithms that can provide accurate target recognition on this data for all possible conditions.

APPROACH

The first task required integrating the existing Northrop Grumman AQS-14A(V1) vehicle into a Coastal System Station (CSS) tow vehicle selected for the program. The installation approach required installing the entire AQS-14A(V1) vehicle less the nose and tail sections and the sonar sensor pod. The plan required design and manufacture of endcaps replacing the nose and tail sections as well as plugs for the sonar sensor and environmental penetrators. Design of mounting hardware used to secure the sensor to the CSS shell section which will house the Northrop Grumman (NG) sensor was also necessary. Communication and power to and from the NG sensor is provided by a separate AQS-14A(V1) coaxial tow cable connected to the NG topside console. This cable is joined to the CSS tow vehicle cable at three feet intervals for the complete length of the cable. The power requirement for the NG AQS-14A(V1) system consists of a 3-phase 400 cycle 120 volt power source able to supply 1kW of power on each phase.

The second task consisted of a data collection effort at CSS. The purpose was to gather as much data as possible with as much variation in environmental and operating conditions. The run matrix for the data collection effort consisted of operating at different speeds, altitudes from the bottom, and different ambient light conditions. The hope was that a variety of water conditions would also occur that would provide us with more and different data. Also planned is a series of data collection runs with variations in the sensor parameters such as video gain and aperture width variations.

The ATR effort will use the data collected from the second task to generate, develop, and verify an algorithm for target recognition under all types of operating and environmental conditions. This work is being done by the Image and Information Research (IIR) group.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**
4. TITLE AND SUBTITLE **Electro-Optic Identification (EOID) Research Program**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Northrop Grumman Oceanic and Naval Systems,,P.O. Box 1488,,Annapolis,,MD, 21404**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The goal of this research is to provide EOID sensor data from two two-week data collection efforts to be used for Laser Line Scan (LLS) sensor model validation. In addition, this data will also be used for algorithm generation and verification for an Automatic Target Recognition (ATR) effort.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Another effort included the characterization of our LLS Sensor and to present the information for model validation.

WORK COMPLETED

The AQS-14A(V1) vehicle conversion to the EOID sensor was completed prior to the data collection effort. The conversion consisted of removing the nose and tail sections and the sonar pod section from the AQS-14A(V1), performing minor electrical modifications, and adding new pressure tested endcaps and penetrator plugs to the sensor shell (See Figure 1). From this configuration, the sensor was then loaded into a CSS provided shell section which is used as a drop-in section to the CSS towed vehicle.

Figure 1. Northrop Grumman EOID Sensor
Photo: sensor section with its endcaps and penetrator plugs attached.

A two-week data collection effort took place in mid-August. Data was collected on seven days with varying environmental conditions. Some CSS vehicle control problems were evident which reduced the amount of data collected on 2 of the days.

The data collected from this effort is being reviewed and passed to the NG IIR group for the ATR algorithm generation. The baseline algorithms are developed from earlier NG work on algorithms to screen man-made-objects in underwater EO images. Initial validation of NG EOID ATR approach has been completed with earlier preview data from the NG Laser-Line-Scan (LLS) camera. The expanded database collected from the data collection effort is being used to further refine and train the algorithms.

RESULTS

Some NG EOID sensor lab characteristics were determined for LLS model validation purposes. These characteristics are shown below:

MTF Testing. Reflectances for black and white tri-bar targets were measured with a Macbeth 927 Densitometer; the black bars were approximately 3% reflective and the white paper background was approximately 79.5% reflective. The bar target sizes were chosen to generate spatial frequencies at 3, 5, 7, and 11 times the "1^{st} Bar" spatial frequency in order to convert the measured square wave response into MTF. During testing, bar sizes smaller than about 0.18" proved difficult to measure and were generally ignored. This means that as the "1^{st} Bar" size became smaller, there were fewer terms in the MTF conversion equation (see below).

Measurements were performed in air at the center and at one edge of the scan line (0° and +35°) with the cylindrical correction lenses both in place and removed. The laser line scanner was not inside its shell, so the measurements do not include any effects from the cylindrical pressure windows (or from water, of course). The measurements were made by capturing the data from a scan line with a logic analyzer and recording the highest white portion and the lowest black portion of a particular tri-bar target. The hexadecimal values from the logic analyzer were converted to decimal values and the square wave response was calculated from the equation:

$$r(n) = \frac{white - black}{white + black}$$

The MTF was calculated from the various square wave response measurements by the equation:

$$R(n) = \frac{\pi}{4}\left[r(n) + \frac{r(3n)}{3} - \frac{r(5n)}{5} + \frac{r(7n)}{7} + \frac{r(11n)}{11} \right]$$

The MTF calculations are summarized in Figure 2.

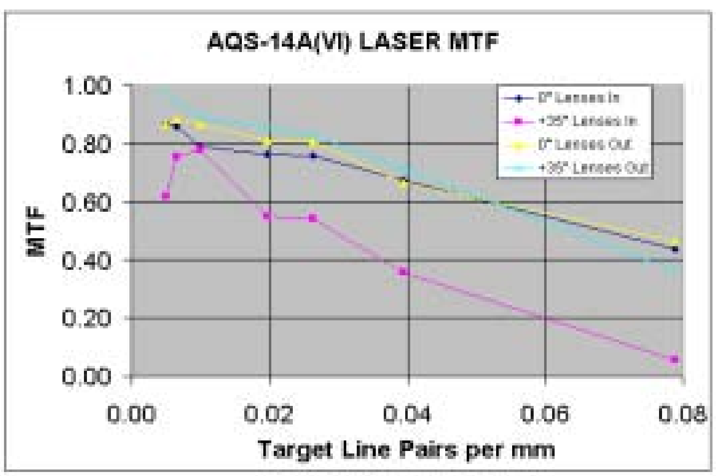

Figure 2. Sensor MTF
Graph of Calculated MTF vs. Target Line Pairs/millimeter
Graph: MTF decreases similarly for 4 conditions of lenses in/out at viewing field 0 degrees and +35 degrees. General slope is .867 at .0049 to .460 at .0787.

Laser Power. The laser power was measured with a Coherent power meter. The measurements were made near the surface of the cylindrical correction lenses and at 11 feet from the scanner. The power meter was angled toward the scanner to get the highest power reading at each measurement spot. The ambient power was about 2 mW. The measurements showed about a +/-1 mW variation in power across the 70 degree scan line at 0 feet (140mW) and about +/- 3 mW variation at 11 feet (128mW).

Relative Edge Response. The relative edge response was measured at the center of the scan line (0°) at two scan speeds, 980 RPM and 3337 RPM. The measurements were made using the 4 inch tri-bar target, with the cylindrical correction lenses in place. The signal levels are shown in Figure 3.

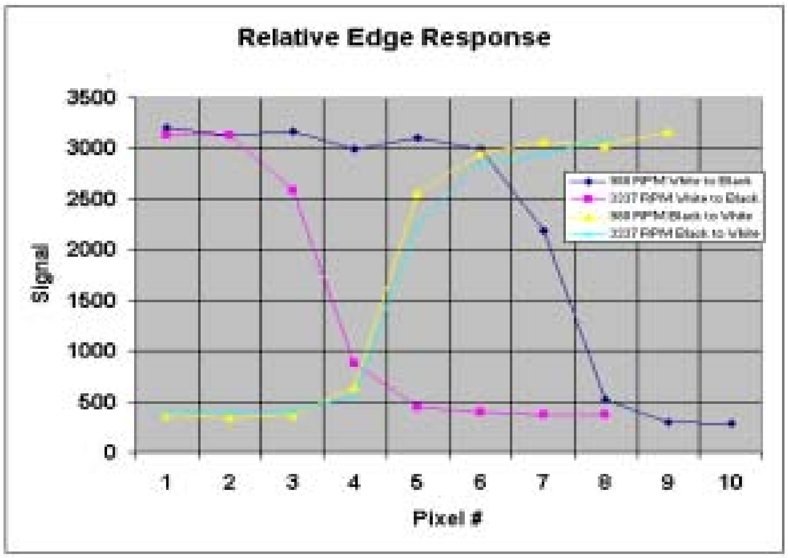

Figure 3. Relative Edge Response
Graph of Signal (data) value vs. Pixel (sample) number
Graph: Four Scenarios of white-to-black and black-to-white for RPM rates of 980 and 3337 are shown to take up to 2 pixels to transition 90%+ in signal value.

Other Measurements. The noise floor of the PMT was measured between 4 and 8 digital counts out of 4096. This measurement was made with the laser power off, the apertures closed, and at two PMT voltages, 340 and 390.

The Northrop Grumman EOID ATR developmental architecture processes the underwater images in multiple steps using multiple processes. The architecture is illustrated in Figure 4 with information flow from top to bottom.

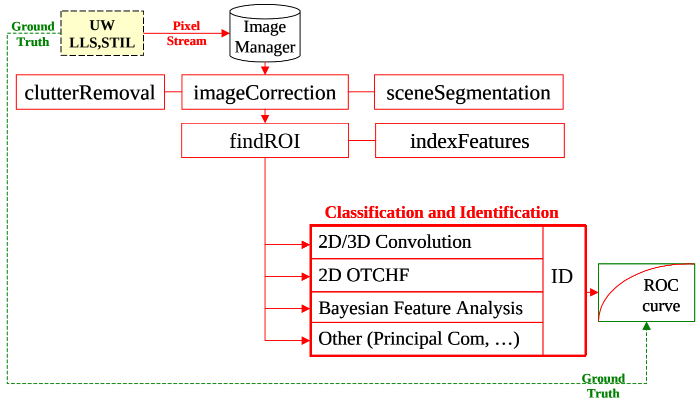

Figure 4. ATR Architecture
Flow diagram from image manager to image correction to find ROI to ID algorithms

The **Image Manager** process provides an image to the EOID processing steps. If the application is development or post processing then the image is read from a file. If the application is real-time then the image is formed from a sensor stream of pixels. Remaining steps are as follows.

- Pre-processing removes image clutter, distortions, and other anomalies and prepares the image for later processing.
- Next region-of-interest (ROI) snippets are found by scanning the entire image.
- Features are extracted from the ROI to parameterize later classification stages.
- Finally an identification stage classifies the ROI as a mine and identifies the type of mine. The following classification identification algorithms will be tested and validated for the ID stage of Northrop Grumman EOID ATR subsystem.
    - Convolution ID is performed by testing an image with filters for each mine type at a particular pose angle. If 3D image data is available, then a 3D convolution will be performed. The convolution is done in the Fourier domain to take advantage of shift-invariance and robustness to distortions.
    - OTCHF ID is an optimised way to build a 2D convolution filter that takes advantage of the top-down view of the object. OTCHF filters span a wider range of angles than simple convolution filters.
    - Feature ID is obtained by training ROI features from ground truth and clutter data for Bayesian likelihood analysis.
    - Other ID approaches may also be tested including: principal and independent component analysis, and pixel probability analysis.

IMPACT/APPLICATIONS

Excellent ROI detection has been developed for the ATR effort. This effort will greatly improve the probability of detection and identification without fully relying on operator assistance.

TRANSITIONS

The lab characteristics listed above are being passed on for implementation into the LLS model validation effort.