Coastal Benthic Optical Properties
Fluorescence Imaging Laser Line Scan Sensor

Dr. Michael P. Strand
Naval Surface Warfare Center
Coastal Systems Station, Code R22
6703 West Highway 98, Panama City, FL 32407
phone: 850-235-5457 fax: 850-234-4867 email: strandmp@ncsc.navy.mil

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LONG TERM GOALS

Identification of mine-like contacts (MLCs) remains a pressing fleet need. During MCM operations, sonar contacts are classified as mine-like if they are sufficiently similar to signatures of mines. Each contact classified as mine-like must be identified as a mine or not a mine. During MCM operations in littoral areas, tens or even hundreds of MLCs must be identified. This time consuming identification process is performed by EOD divers or ROVs, and is the rate limiting step in many MCM operations. A method to provide rapid visual identification of MLCs would dramatically speed up such operations. Acquisition of Electro-Optic Identification (EOID) sensors for MLC identification is currently underway to support both Air Mine Counter-Measures (AMCM) and Surface Mine Counter-Measures (SMCM) operations.

The scenario outlined above is viable in acoustically benign environments, but faces many obstacles in highly cluttered environments. Coral reefs are a prime example of an environment where current acoustic methods can be expected to have great difficulty. Our prototype Fluorescence Imaging Laser Line Scan (FILLS) sensor[1,2,3,4] has demonstrated that fluorescence imagery provides strong signatures which may be used to separate the coral clutter from mines. The image above demonstrates the ease with which a human observer can differentiate the mine like objects (MLOs) from the natural clutter in an environment that is difficult for sonars. Accordingly, this technology is a leading candidate for **extending MCM capabilities into highly cluttered environments**. In this role, FILLS imagery can be used for MLC detection, classification, and identification.

OBJECTIVES

The objective is to explore the exploitation of FILLS imagery to extend MCM capability into highly cluttered environments. This includes establishing a firm understanding of the elastic scatter and fluorescent scatter signatures of mines, clutter, and natural backgrounds, and exploring algorithmic approaches to exploit fluorescence to locate manmade objects, while rejecting coral clutter.

APPROACH

The approach followed is to use existing sensors to acquire FILLS data relevant to MCM operations. The data thus acquired is being analyzed in order to explore the exploitation of FILLS imagery for extending MCM capability into highly cluttered environments.

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14. ABSTRACT
Identification of mine-like contacts (MLCs) remains a pressing fleet need. During MCM operations, sonar contacts are classified as mine-like if they are sufficiently similar to signatures of mines. Each contact classified as mine-like must be identified as a mine or not a mine. During MCM operations in littoral areas, tens or even hundreds of MLCs must be identified. This time consuming identification process is performed by EOD divers or ROVs, and is the rate limiting step in many MCM operations. A method to provide rapid visual identification of MLCs would dramatically speed up such operations. Acquisition of Electro-Optic Identification (EOID) sensors for MLC identification is currently underway to support both Air Mine Counter-Measures (AMCM) and Surface Mine Counter-Measures (SMCM) operations.

15. SUBJECT TERMS

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The primary sensor used by this project is the prototype FILLS sensor. This is supplemented with a Reson Seabat 6012 ahead looking sonar which is used for target reacquisition, and a down looking Seabat 9001 sonar, which provides swath bathymetry information.

The test site selected for CoBOP is the Caribbean Marine Research Center (CMRC) on Lee Stocking Island (LSI), Bahamas. This site was selected because it provides research support facilities in environments compatible with the overall objectives of CoBOP. The environments available include coral reefs, sediments, and sea grasses. Specific study sites in each of these environments were selected by CoBOP.

WORK COMPLETED

The FILLS sensor was deployed at the CoBOP LSI test site during the May 1998 field test[5,6]. FILLS imagery was obtained of coral reefs, sediments, sea grasses, and various other targets including mine-like objects. The FILLS and Seabat sensors were integrated into a CSS active depressor towed body for the 1999 and 2000 LSI field tests. This integration was fully successful, and FILLS imagery was successfully obtained of all the desired target environments (sediments, sea grasses, and coral reefs) and targets (MLOs and fluorescence panels) at North Perry, Rainbow Gardens, Adderly Cut, and Channel Marker.

In FY01-02 the attention was focused on development of algorithms to utilize the fluorescence information to highlight manmade objects in FILLS imagery, while rejecting the coral reef clutter in the imagery. The approach investigated exploits the fact that manmade objects mask the fluorescence signals from the underlying sediment, creating “holes” in the fluorescence signals. Locating the “holes” in the fluorescence images was done by calculating the mean and standard deviations of the fluorescence returns from “sediment-like” regions of the image. Sediment-like regions were characterized by small local variations in the image for each of the four channels, while the coral regions are characterized by larger local variations in the return. A “local standard deviation” calculation was used to construct a mask to differentiate the coral-like and sediment-like regions of the image. This mask was used to compute statistical properties of the sediment portions of the image. The “holes” in the fluorescence image were identified by thresholding the fluorescence image returns as compared to the statistical properties of the sedimentary portions of the image. This procedure has been documented in a conference paper presented at Oceans 2001 in November 2001. In FY02 these algorithms have been extended and refined in order to make them more robust and more automatic.

In FY02 a design concept was developed for a compact FILLS sensors. This design concept will allow fabrication of a FILLS sensor with a fraction of the size, weight, and power requirements of the existing FILLS prototype sensor. Such a design is a requirement of practical deployment of FILLS technology to enable MCM in cluttered littoral environments.

Thus far FILLS data has not been submitted to a national data archive.

RESULTS

It has been clearly demonstrated that the type of sediment strongly influences the background fluorescence signal. The masking of the fluorescence from the sediment is what is exploited by the algorithmic approach pursued in FY01-02 for highlighting manmade objects while rejecting clutter from the coral reef. Figure 1 shows the images from each of the four channels, as well as a pseudo-color image formed from the fluorescence channel imagery. Figure 2 shows the background masks formed from the local standard deviation of the each of the four channels, as well as a composite mask formed by AND-ing the masks from the four individual channels. It is evident that this composite mask separates most of the coral (and some of the manmade objects) from the sediment. This mask is used to compute the statistical properties of the sediment, for use in thresholding to find the “holes” in the fluorescence signals, indicating manmade objects. Figure 3a-b show the object masks formed by thresholding the red and yellow fluorescence channel images, respectively. Figure 3c shows the composite object mask formed by AND-ing the red and yellow masks. Figure 3d shows the final object mask, formed by cleaning up the 3c mask using standard mathematical morphology operations. This final mask selects the manmade objects, while rejecting the extensive coral clutter.

Figure 4 shows similar results from a quite different environment. The algorithm successfully finds the 4 mines surrounding the upper coral, while rejecting the coral clutter. It also successfully finds the six resolution panels below the upper coral. There are also 2 targets above the upper coral. These targets were designed to have strong fluorescence signatures. As expected and desired, the algorithm does not select these targets. For this data run there was a significant change in the altitude of the sensor during the run over the target field. The algorithm successfully dealt with the changing signal strength associated with this change in altitude.

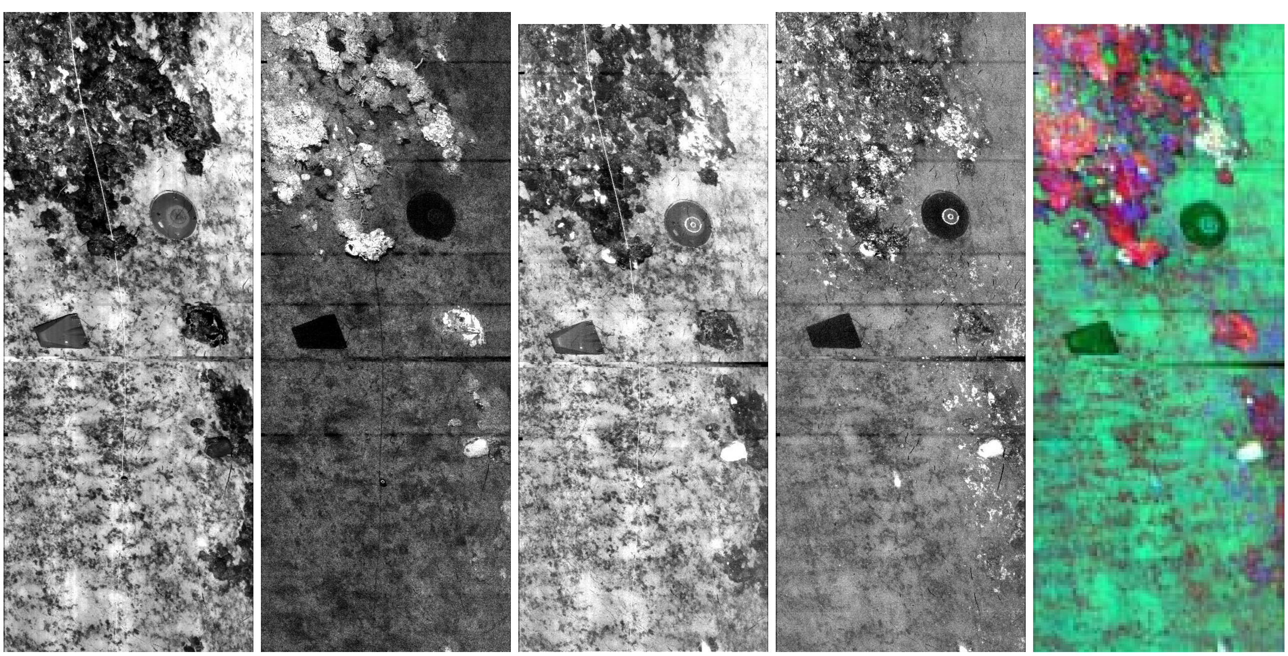

Fig. 1. The images produced by the a) elastic scatter channel, b) red fluorescence channel, c) green fluorescence channel, and d) yellow fluorescence channel. e) shows the pseudocolor image produced by mapping the red, green, and yellow channel images to RGB, respectively.

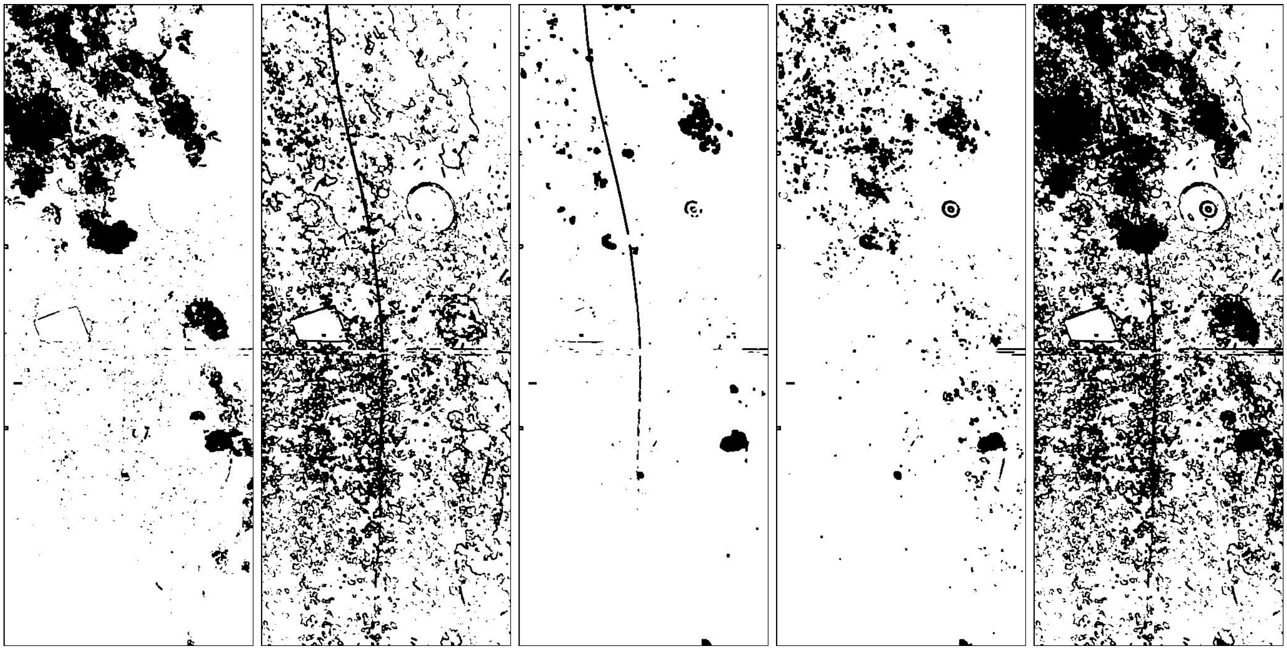

Fig. 2. The Local Standard Deviation (LSD) background masks formed from the elastic, red, green, and yellow images are shown in subfigures a-d), respectively. Subfigure e) shows the composite LSD background mask formed by AND-ing the LSD background masks form the 4 channels.

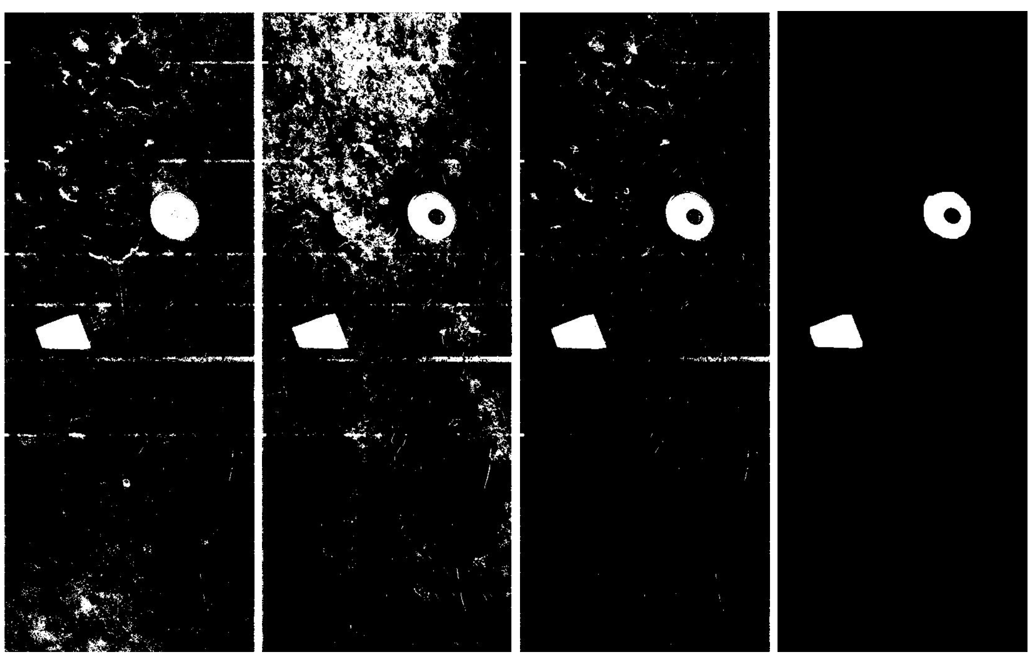

Fig. 3. a) and b) show the background masks formed by thresholding the red and yellow channel images, respectively. c) shows the AND-ing of masks a) and b). d) shows the final object mask formed by cleaning-up mask c) using standard mathematical morphology operations. This final mask selects the manmade objects, while rejecting the extensive coral clutter.

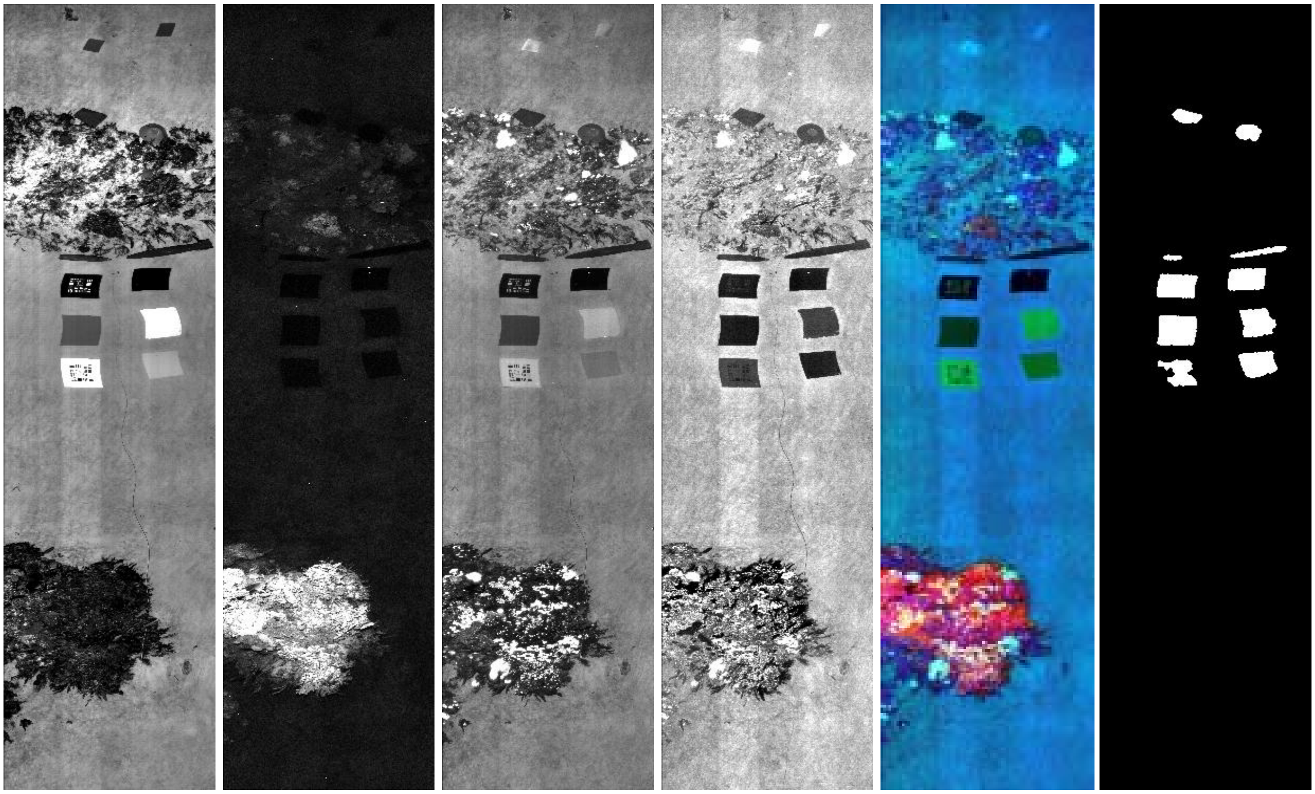

Fig. 4. a) through e) show the elastic, red fluorescence, green fluorescence, yellow fluorescence, and pseudocolorfluorescence images, respectively. 4f) shows the composite target mask generated, selecting the mines and target panels, while rejecting the coral clutter. The 2 objects near the top of the image were designed to have moderately strong fluorescence signatures. As expected and desired, these objects are rejected by the algorithm

IMPACT/APPLICATIONS

Results obtained by this and related CoBOP projects are expected to play a key role in the decisions of what technology to pursue for the next generation Advanced Electro-Optic Identification Sensor.

TRANSITIONS

This work is one of the ONR sponsored projects that have lead to the transition of EOID sensors to the fleet to support both AMCM and SMCM.

RELATED PROJECTS

This project is closely coordinated with the Coastal Benthic Optical Properties (CoBOP) DRI. This project is studying the optical signatures of backgrounds, clutter, and targets. These signatures are key to the development of the automatic target detection algorithms required to support AMCM and SMCM.

PUBLICATIONS

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