Coherent Feature Extraction For Detection and Classification of Underwater Targets From Multiple Disparate Sonar Platforms

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Problem & Objectives of the Research:

A critical need of the U.S. Navy is the development of a reliable, efficient and robust underwater target detection system that can operate in real-time with multiple disparate sensor systems and in different environmental and operating conditions. In a surveillance area there could be multiple UUVs each equipped with a wide variety of sensors including different types of sonar, magnetics, or electro-optical (EO) systems. The development of a robust underwater target detection and classification system that can operate with multiple disparate sensor systems and in different operating conditions poses many technical challenges. In the traditional centralized processing, preliminary detection, feature extraction and object classification are performed based upon the data collected using every sensor platform. A final decision-making usually takes place at the central station, either in the post-mission analysis (PMA) or real-time network-centric sensor analysis (NSA) modes, using some type of a decision, feature or combined fusion mechanism. However, decision-making based upon individual sensory data typically leads to incomplete, degraded or biased local (sensor-level) decisions hence resulting in an unacceptable final detection and classification performance at the fusion center.

In the collaborative decision-making using several sensor platforms, it is essential to detect and further scrutinize the information-bearing parts of the data collected by various platforms. This involves detecting, isolating and representing, in terms of some pertinent attributes, the coherent or common information among the multiple data sets. This is an extremely challenging problem due to the disparate nature of the problem and variations in the operating conditions. Thus, to develop a system-level solution, new methodologies are needed to: (a) collaboratively detect and agree on threats occurring within the field of view of the sensors, (b) perform collaborative feature extraction to capture common target attributes from multiple sensor platforms, (c) perform object classification and identification, (d) and finally develop a single integrated target assessment picture based upon the detected, localized and classified targets from multiple disparate sensors.

The objectives of this research project are the development and testing of a multichannel coherence-based detector using the Multichannel Coherence Analysis (MCA) framework which finds a set of linear mapping functions that maximize the sum of the correlations among all N channels. This detector exploits the coherence of objects present in N disparate channels based on the assumption that the presence of objects in all data sets will lead to a higher level of coherence compared to that of noise alone. New expressions for the log-likelihood ratio and J-divergence measure of detectability in the MCA framework are developed. These terms will be used not only for the simultaneous detection of targets from N disparate sonar data but also to find the subset of coordinates that bring the largest improvement in detectability producing low rank detectors. The proposed detection framework will then implemented and tested on multi-sonar data sets provided by the Naval Surface Warfare Center Panama City Division (NSWC PCD).
**Results:**

The data set for our study is a multi-platform sonar database of images collected by the Naval Warfare Surface Center (NSWC) at Panama City, Florida. The data set contains a high frequency (HF) high resolution sonar image over the target field and three broadband (BB) sonar images co-registered over the same region. The two images are disparate in spatial resolution and frequency content. The targets were implanted in various background and clutter densities and vary in size and clarity in the sonar images. All detectors in this study were constructed with the HF image along with one to three BB images to take advantage of the high resolution capabilities of the HF sonar for the detection of the targets along with the clutter suppression abilities of the BB sonar. Figures 1 (a)-(c) display statistics of the MCA correlations for Regions of Interest (ROIs) containing targets and background for the two, three, and four channel detectors, respectively. From these figures, we can see a suitable amount of separation in the correlations between targets and background. Using J-divergence as an information measure for performing rank reduction, Figure 2(a) displays Area Under the Receiver Operating Characteristic (ROC) curve (AUC) as a function of the degree of rank reduction. Using this as a guide, Figure 2 (b) then shows histograms of the rank of each detector. From Figures 2 (a) and (b), it is clear that J-divergence can effectively be used to reduce the rank of the multichannel detector while maintaining high performance. Finally, Figures 3 (a)-(c) display the ROC curves for the MCA-based detector as well as those for a Generalized Likelihood Ratio Test (GLRT) designed to also search for large levels of coherence. From these figures we can see that the addition of a BB image to all three two-channel detectors brings substantial improvement for their three-channel versions. However, adding yet another BB image seems to bring little if any improvement in detection performance in all three cases suggesting a point of diminishing returns.

**Recent Publications:**


**Acknowledgment:**

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a) Two Channels

b) Three Channels

c) Four Channels

Figure 1: Multichannel Correlations for all Three Channel Configurations.

a) AUC vs. Rank Reduction

b) Rank of the Detectors

Figure 2: Performance vs. Rank Reduction and Rank Histograms of the Detectors.
Figure 3: ROC Curves for all Three Channel Configurations