Innovative Background Noise Removal Technique for Underwater Target Detection and Classification

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Many active and former military installations contain firing ranges and training areas adjacent to aquatic environments, including ponds, lakes, rivers, estuaries, and oceans. In some cases, training and testing activities were deliberately conducted in these water environments. Additionally, disposal activities and accidents have led to significant munitions contamination in both coastal and inland waters of the United States. Consequently, in addition to land-based unexploded ordnance (UXO contamination, up to a million acres of underwater (UW) environments may be contaminated with UXO.

Advanced electromagnetic induction (EMI) sensors, such as multi-angle illumination systems with 3-axis vector sensing and multi-static array sensors producing multi-sight-angle measurements, have demonstrated excellent classification performance for detecting and discriminating subsurface metallic targets on land. While techniques used for land-based detection may apply to UW UXO detection, utilizing a sensor array positioned either above or below the water surface, the unique background EMI signals introduced by the UW environment can degrade target signals and complicate classification, particularly in moderate signal-to-noise ratio (SNR) scenarios.

To address this challenge, our group has developed and demonstrated an innovative noise mitigation technique called the gradient method. This technique removes sensor and background noise by subtracting the previous observation from the current one. Compared to the standard detrending method—effective at eliminating broad, smooth background signals but less reliable in regions with rapidly fluctuating and low-SNR signals due to sensor movement or complex UW noise environments—the gradient method provides superior performance in extracting target signals amidst rapidly changing noise and complex signal structures. This enhances its effectiveness in isolating signals from compact, deep targets and improving target-background separation in UW environments.

This paper presents UW targets' detection and classification performance based on UW EMI datasets collected at Sequim Bay in 2022. Data were acquired at low and high elevations using a fast (90 Hz) frequency. Targets were ranked using fingerprinting techniques, where extracted polarizabilities were compared to those of known targets in our reference library. Based on the degree of mismatch between predicted and library polarizabilities, the targets were sorted, and a ranked list was generated. This list was submitted to the Institute for Defense Analyses (IDA) for independent evaluation, yielding excellent classification results. Namely, the algorithm identified 65 detections for the low-elevation dataset, of which 45 were classified as targets of interest (TOI). The final dig list was submitted to IDA for scoring. The classification results showed that 35 of the 45 TOIs were correctly identified, while 6 were false positives. Similarly, for the high-altitude ULTRATEM dataset at Sequim Bay, the algorithm identified 93 anomalies, of which 51 were classified as TOIs and marked for excavation. Among these 51 TOIs, 35 were true and 12 false positives, respectively. Four anomalies initially identified as TOI were removed from both scoring lists due to significant drift from their original geolocations.

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