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OCEAN ACOUSTICS AND SIGNAL PROCESSING FOR ROBUST DETECTION AND ESTIMATION

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Long Term Goals

The long term goal of this project is to develop fast and intelligent signal processing algorithms for successful detection and estimation by incorporating (fully or partially) the physics of the propagation medium. Algorithms will be designed for robust ASW detection and localization and also for marine mammal localization and tracking.

Objectives

1. Develop a fully coherent (across space and frequency) matched field processor for source localization, taking into account the spatial coherence of the acoustic field across different frequencies for more robust localization performance.
2. Improve standard (receiver-source) matched filters for better active detection performance without extensive calculation of replica fields.
3. Reduce the computational requirements of passive and active matched-field processing by reducing parameter spaces to smaller subspaces based on the correlation structure of parameters.

Approach

A passive, coherent matched-field processing scheme originally developed by the PI for application to the Hudson Canyon data has been extended. The new processing scheme is more robust with respect to noise than the previously developed coherent processor and standard incoherent matched field processing methods. It is evaluated with simulations using normal modes to model sound propagation and Monte Carlo runs to quantify localization performance. Performance is being assessed in shallow water environments that replicate quite accurately data collection in the ocean by accounting for ambient noise and uncertainty with respect to signal arrival times.

Active time-domain matched field processing is also currently pursued. Data from the Swellex 96 experiment are studied in order to evaluate the detection gain from implementing a replica-based (model-based) matched-filter instead of a standard source-receiver matched-filter.

Results

The new coherent matched-field processor makes use of the arrival times of the signals in order to estimate the source spectrum, which is then exploited through implied cross-frequency correlation structure. It has been shown with simulations that the coherent processor provides much more accurate localization in low SNRs than conventional, incoherent matched-field processing. The results indicate that the coherent scheme improves the spatial sampling of the propagation medium and is, therefore, particularly advantageous when sparse arrays are used for data collection. The processor has been evaluated in the presence of arrival time uncertainty and determined to be robust, especially when several (20 and more) observations are available for the estimation of the coherent covariance matrix.

Time domain processing with both simulations and the Swellex data has demonstrated the (expected) superiority of the replica-based matched filter in target detection. To improve efficiency the significant computational requirements of the replica based matched filter are circumvented through the development of a simplified matched-filtering technique. This new technique is an extension of a simple source-receiver matched-filter: Instead of sole reliance on the highest peak to make a detection decision the filter also investigates secondary maxima of the correlation function. The detection scheme has been evaluated with synthetic data and appears to be superior to the simple matched-filter but poorer than that of the optimal model-based matched-filter.

Impact

The coherent matched-field processing scheme offers improved estimation results compared to its conventional, incoherent counterpart and is a promising tool for successful ASW localization. The new processor also has the appealing property of a very straightforward implementation relying on the standard Bartlett structure.

The active domain matched-filtering technique, which is a simple extension of a matched-filter, is a portable method, independent of environments. It is computationally inexpensive and improves the standard matched-filter detection performance. The results are promising and indicate the feasibility for the design of a new processor that is a successful detector of targets in the ocean requiring fewer resources than the model-based matched filter.

Related Projects

The described work is closely tied to work performed in collaboration with Dr. Peter Gerstoft on optimization techniques and matched-field processing. Results of this collaborative effort are expected to enhance both active and passive aspects of the project.