Detection and Tracking of a Moving Source with Application to Real Data (SWellEx-3)

Stacy L. Tantum and Loren W. Nolte

Department of Electrical Engineering, Duke University, Durham, North Carolina, 27708

Abstract: The optimum uncertain field tracking algorithm (OUFTA) incorporates knowledge of source motion as well as uncertainty in the propagation environment [S. L. Tantum and L. W. Nolte, “Tracking and localizing a moving source in an uncertain shallow water environment,” J. Acoust. Soc. Am. 103, 362-373 (1998)]. In this paper, it is shown how detection, tracking, and adaptivity to an uncertain environment can be formulated within a unifying and optimal framework. Results are presented using this approach with low signal-to-noise ratios and real data (SWellEx-3).

OPTIMUM UNCERTAIN FIELD TRACKING ALGORITHM

The passive detection, localization, and tracking of submerged acoustic sources in shallow coastal waters is a challenging problem because in addition to the complicated multipath nature of the acoustic propagation, there often are many uncertainties concerning the parameters which describe the acoustic environment. Matched-field processing exploits the multipath environment and provides an effective method for source localization when the propagation model is completely known. Matched-field tracking, a technique which extends the concept of matched-field processing to include modeling of the source dynamics, has recently emerged as a promising approach for tracking a moving source. The optimum uncertain field tracking algorithm (OUFTA) (1) considers the uncertainty in the environment and introduces a Markov model for the source motion as a means of capturing the source dynamics without assuming uniform motion.

The OUFTA implements the optimal approach to tracking a moving source in the presence of environmental uncertainty. By extending the optimum uncertain field processor (OUFP) (2) to include modeling of the source motion in addition to the uncertainty in the ocean, the a posteriori conditional probability of the source path given the sequence of $k$ data observations, $p(S_k|R_k)$, can be computed. From this the MAP estimate of the source track can be determined. The OUFTA utilizes the nature of the source motion as well as the assumption that the environment does not change while the source is being tracked. This enables the OUFTA to increase its knowledge of the uncertain parameters as more data is obtained, and improves its performance. The source motion is modeled as a first-order finite-state discrete-time Markov process. This model fits well in the matched-field processing framework since the range and depth are discretized in order to compute the ambiguity surfaces. The desired a posteriori conditional probability can be expressed as

$$p(S_k|R_k) = \frac{p(S_k)}{p(R_k)} \int_{\Psi} p(R_k|S_k, \Psi)p(\Psi)d\Psi = \frac{\prod_{i=1}^{k} p(S_i|S_{i-1})}{p(R_k)} \int_{\Psi} \prod_{i=1}^{k} p(r_i|S_i, \Psi)p(\Psi)d\Psi,$$

(1)

where $\Psi$ is a vector containing the uncertain parameters describing the ocean environment and $p(r|S, \Psi)$ is defined by the OUFP. Ideally, it is desirable to compute the a posteriori probability of every possible source track; however the computational intensity of this task grows exponentially with the number of observations. In principle, this makes implementation of the OUFTA computationally prohibitive. The concepts behind the Viterbi algorithm (3) can be applied to reduce the computational intensity to linear growth with the number of observations and make implementation of this algorithm feasible.

The conventional approach to tracking a moving source is to concatenate the results of a series of independent source localizations. This approach, termed the conventional tracking algorithm (CTA), is quite fast. However, it does not incorporate the a priori knowledge of the source dynamics or carry forth environmental information from observation to observation.
NARROWBAND (197 Hz) TRACKING RESULTS WITH SWellEx-3 DATA

The SWellEx-3 experiment was conducted off the San Diego coast near Point Loma in July 1994. This site is a shallow water channel approximately 200 m in depth with a relatively flat bottom and a downward refracting sound speed profile. A full description of the geoacoustic environment may be found in (4), and details concerning the experiment itself, including the true source track, and broadband (53–197 Hz) tracking results may be found in (5).

The results of processing a narrowband (197 Hz) segment of the SWellEx-3 data (J211-GI track) using both the OUFTA and the CTA are illustrated in Fig. 1. The optimized geoacoustic parameters reported in (6) and the array parameters reported in (7) were used to define the propagation model. The transition matrix is uniform and accommodates source motion of +50 to +150 m/min in range and –20 to +20 m/min in depth. The dashed line shows the actual source path, and the estimated source track is represented by the solid line. These results show the most probable source path determined by the OUFTA provides a better estimate of the source track than the CTA.

ACKNOWLEDGMENTS

The authors would like to thank Bill Hodgkiss of the Scripps Institution of Oceanography for providing the SWellEx-3 data and valuable information about it. Support for this work has been provided by the Office of Naval Research.

REFERENCES