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 efficient inversion algorithms for successful estimation and detection by incorporating (fully or partially) the physics of the propagation medium. Algorithms will be designed for robust ASW localization and detection and also for geoacoustic inversion.

OBJECTIVES

- Achieve accurate and computationally efficient source localization by designing estimation schemes that combine acoustic field modeling and optimization approaches.
- Develop methods for passive localization and inversion of environmental parameters that select features of propagation that are essential to model for accurate inversion.

APPROACH

During the past year, the focus of our research was developing an optimization approach for source localization and geoacoustic inversion based on **tabu** [1, 2]; the work had originated during the previous year and lead into a full inversion scheme during the present year. Tabu is an optimization approach widely used with great success in operations research [1]. Results from application of tabu to seismic data [2] indicated the potential of the method for source localization and geoacoustic inversion. The work was conducted in collaboration with Urmi Ghosh-Dastidar, NJIT.

Further worked was carried out on the estimation of arrival times and amplitudes of multipaths in shallow water environments in collaboration with Michele Picarelli, NJIT.
The Gibbs Sampling approach relies on the identification of appropriate conditional probability distributions for unknown parameters. When those (or at least most of those) are analytically known, obtaining random samples for a Monte Carlo approach is straightforward and facilitates the estimation of a joint posterior probability distribution of the parameters to be estimated. The exhaustive calculation of such multi-dimensional distributions is computationally cumbersome and undesirable, especially when the number of multipaths is large and more unknowns (noise characteristics, for example) enter the problem.

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14. ABSTRACT
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15. SUBJECT TERMS

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WORK COMPLETED

Tabu is a search approach utilizing memory in order to navigate the search space efficiently, avoiding areas already visited, especially those where the objective function takes on small values (for maximization). Tabu is a flexible approach; there are no firm rules on how memory should be managed for optimal performance.

In this work, we developed a tabu optimization scheme for source localization and geoacoustic inversion with a variety of features including several lists for memory purposes. The lists lead the search in a manner that avoids both "undoing" good moves (improvements) and repeating the same search path; thus, the method does not get trapped easily in local maxima and does not invest time in low correlation areas. The method also keeps track of previous moves and field calculations; if parameter sets are revisited, the objective function is not recalculated but is looked-up in memory instead.

Figure 1 shows an ambiguity surface (Bartlett correlation over source range and depth), where the tabu path is indicated with circles. Tabu started from an initial condition of 2 m for source depth and 4.9 km for range; the true source location is at 100 m and 2 km for source depth and range, respectively. It can be seen from the figure that tabu favors high correlation areas and identifies the true source location (there are numerous circles in the area of the true parameter values).

The tabu method we developed and inversion results are analytically presented in [3].

The Gibbs Sampling arrival estimation method introduced in [4] has been substantially extended, incorporating increasing levels of uncertainty and producing results in an efficient manner. The method was extensively tested on multiple environments, studying the robustness and resolution of the approach.

RESULTS

Tabu was applied for inversion to both synthetic and real data. Through application to synthetic data starting from multiple sets of initial conditions, it was evaluated via a comparison to the fast simulated annealing approach of [5]. As a result of the comparison, two observations were made: (i) Tabu performs fewer objective function calculations than the other method for successful identification of the parameter values at which the true maximum occurs and (ii) tabu reaches deeper into the objective function than simulated annealing, that is, it performs an effective local search once the general area of the global maximum is identified, obtaining high objective function values. Consequently, tabu gave very good results even for parameters to which the field is not particularly sensitive (once the significant parameters were estimated, the local searches further improved the correlation function by adjusting the less significant parameters).

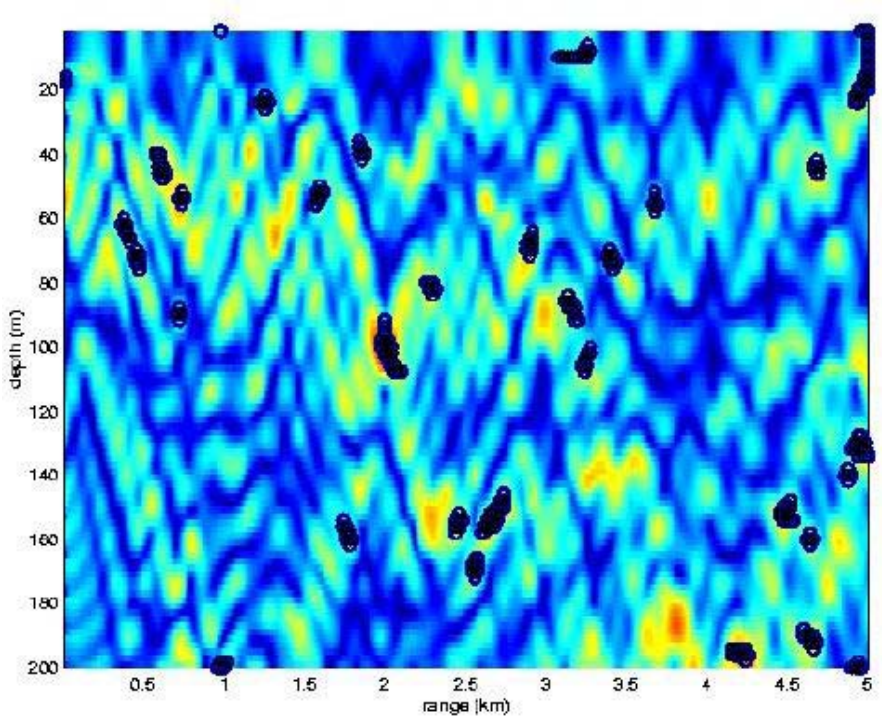

Figure 1: Tabu search superimposed on a source range-depth ambiguity surface.

The ray identification process was tested on real data; it was successfully used for arrival time and amplitude estimation in the Haro Strait. The Haro Strait data set has proved to be challenging and presents complications in inversion because of the complex, range dependent environment. Previous work has shown, however, that substantial information can be extracted from the data, if multipath arrival times are accurately estimated [6,7]. The scope here is to tie these estimates to sound propagation models for estimation of relevant parameters.

IMPACT

The methods developed in this project facilitate both passive and active localization and geoacoustic inversion in the ocean.

Tabu was shown to be very successful in inversion with underwater sound. In addition to source localization, tabu was shown to be a very useful tool in geoacoustic inversion, giving accurate estimated for various parameters. Having the ability to adapt using memory, the potential of tabu can be further explored and the method can be further developed to accommodate the behavior of the acoustic field and optimization function to the involved parameters.

The Gibbs Sampling arrival and amplitude estimation method and its successful application on real data facilitates inversion schemes that rely on such estimates [6,7,8, 9].

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PUBLICATIONS

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Urmi Ghosh-Dastidar, Optimization for source localization and geoacoustic inversion in underwater acoustics, Ph.D. Dissertation, NJIT, May 2003.

HONORS

Zoi-Heleni Michalopoulou was elected a Fellow of the Acoustical Society of America in December 2002.