Source Localization in a Moving Sensor Field

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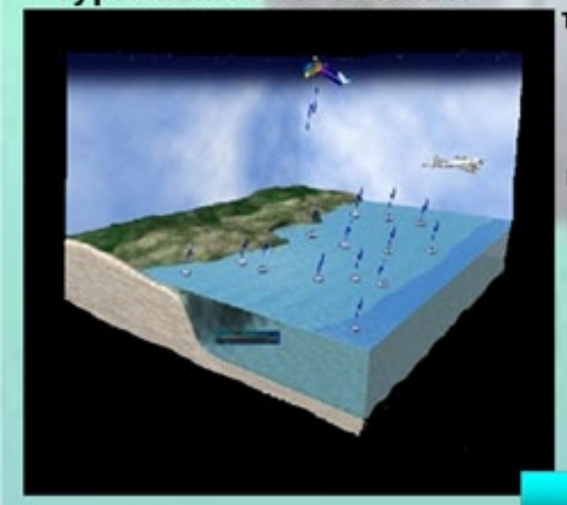
In order to maintain U.S. naval dominance, there is continuing need to develop innovative approaches for near-real-time remote detection of underwater targets. Moving sensor fields can improve detection performance against stealthier targets by achieving large numerical apertures. These sensors are typically sonobuoys, drifting with the wind and the currents. In the past much attention in anti-submarine warfare (ASW) has focused on adaptive beam-forming. There, goals were to achieve robust direction-of-arrival (DOA) estimation. The focus of this project is on determining the time difference of arrival (TDOA) of a source wave front between the sensors of the irregularly distributed array. Because of the absence of a timing reference for the source-to-be-located (e.g., target submarine), the most commonly used technique for TDOA estimation is cross correlation, since it enables synchronization of all the contributing sensors. In practice, estimated TDOAs must be computed for each pair of sensors *n* and *m* from signals $x_n(t)$ and $x_m(t)$ measured at the corresponding sonobuoys. In fact, the cross correlation compute from the cross-power spectral density of the data sequences acquired at each sensor, rather than using the conventional correlation formalism. Moreover, to sharpen the correlation peak, the generalized cross correlation paradigm is adopted, where a frequency weighting filter is included prior to taking the inverse Fourier transform of the cross-power spectrum. These simulations were performed using synthetic sensor data, which show excellent agreement with analytically computed TDOAs.

Objectives

- Compute time difference of arrival (TDOA) from sensor sampled data of the source wavefront for each pair of sensors in the network
- Use techniques that enable extraction of week signals corrupted by strong clutter

Typical Mission Scenario

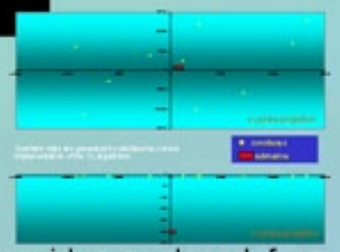


Typical mission configuration

- Submerged submarine
- Patrol aircraft searching for it
- A filed of GPS capable sonobuoys

Buoys are passive omnidirectional sensors

- Provide sound pressure measurements of target signal and ambient noise
- Continuously monitor and transmit sensed data via radio link
- Periodically sample their positions, which are also transmitted via radio link



Software

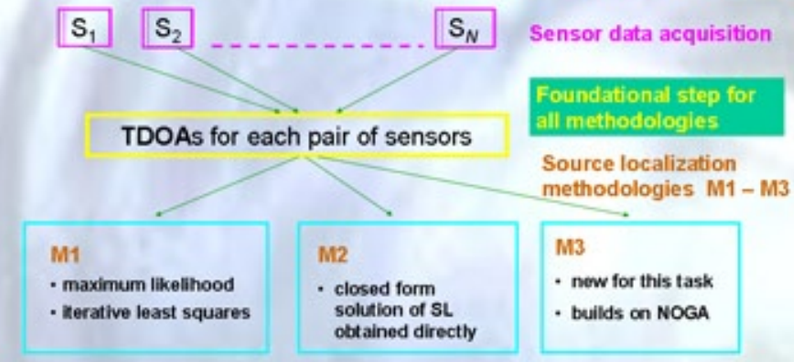
Compaq Visual FORTRAN

Future Plans

- Implement algorithm that provides a closed form solution to source localization problem using TDOAs
- Use Visual FORTRAN 95

Methodology

- Information Flow



- Generalized Cross Correlation

  Frequency weighting filter ψ is introduced to sharpen the correlation peak

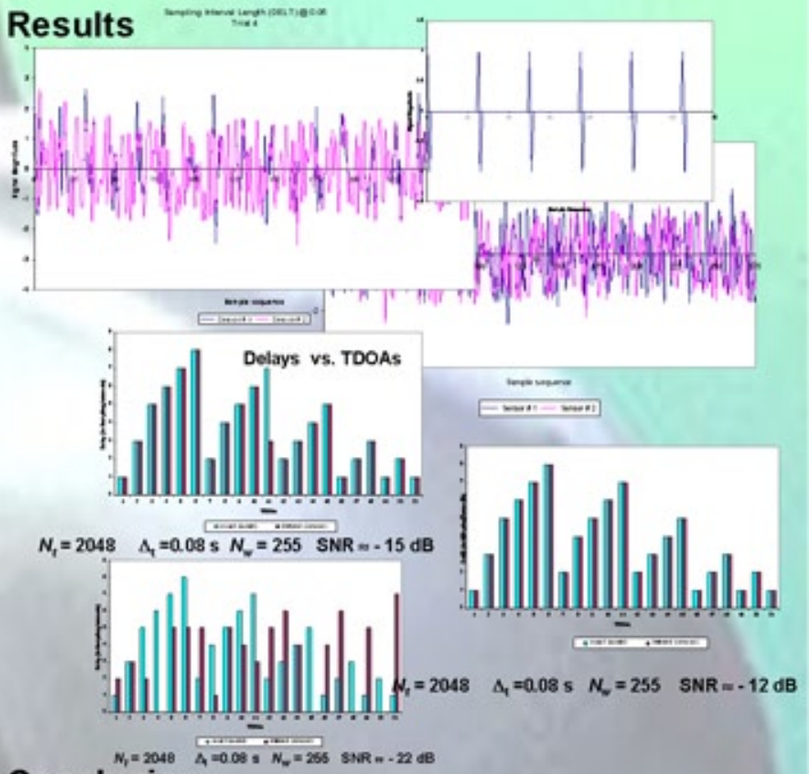
$$\hat{R}_{x_m x_n}(\tau) = \int_{-\infty}^{\infty} \psi(f)\, \hat{G}_{x_m x_n}(f)\, e^{j\pi f \tau}\, df$$

The GCC provides a coherence measure that captures, for a hypothesized delay, the similarity between signal segments extracted from sensors *n* and *m*.

- Cross – Power Spectrum

  The basic idea behind the spectral cross power, *G*, scheme is to exploit the fact that two real, discrete data sequences can be *Fourier transformed simultaneously*. The sensor data are processed in "windows" to damp the noise effects. The TDOAs correspond to the maximum of the cross correlations.

Results



Conclusion

The upper three figures show the actual target signal and its echoes embedded in clutter as received at two sensors at two very low (negative) SNRs. As can be observed, the signal is indistinguishable. The lower figures compare TDOAs, for successive pairs of sensors, estimated from the sensor data with analytically derived results, and show excellent agreement. Note that as the clutter becomes more dominant, discrepancies begin to appear.

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