University Defence Research Collaboration in Signal Processing

LSSC Consortium White Paper

Adaptive Bayesian Sparse Representation for Underwater Acoustic Signal De-Noising

Introduction

Passive sonar can be used to detect and track the direction of moving underwater targets. This is a particularly challenging problem due to the nature of the underwater acoustic environment. There are often multiple sources and multiple reflections, particularly from the surface of the water, causing a high degree of noise. In order to avoid detection passive listening devices are preferred, in this case hydrophone arrays, which are included in the system depicted in the image below found at http://i-hls.com/2013/02/dsit-ltd/ . In passive systems one or more receiving sensors or hydrophones are used to record the ambient acoustic signal, therefore unlike active sonar systems there is no control over the strength of the received signal from the object we wish to track. Therefore we are presented with the very challenging problem of separating and tracking very weak acoustic sources in a high noise environment. We exploit an adaptive sparse sequential Bayesian approach which uses a sequential sparse Bayesian approach for underwater source separation and tracking.

Method

In the problem of estimating the Direction of Arrival (DOA) of underwater acoustic sources we have a series of Fourier transformed measurements from our sensor array at each time step. We also have at each time step a vector of possible angles each being a potential source direction (DOA). We also have a matrix where each column of this matrix represents a steering vector for the sensor array corresponding to a particular source direction. Given a sequence of inputs over time from the sensor array we wish to find the Maximum a Posteriori (MAP) estimate of the DOA for a limited number of sources at each time step. The approach presented by Mecklenbruker et al. [1] extends sparse reconstruction methods to sequential data. This is done by extending the classic Bayesian approach to a sequential MAP estimation of the signal over time. A sparsity constraint is enforced through the use of a Laplacian like prior at each time step, this limits the number of sources being tracked. An adaptively weighted LASSO cost function is sequentially minimised using each new array measurement.

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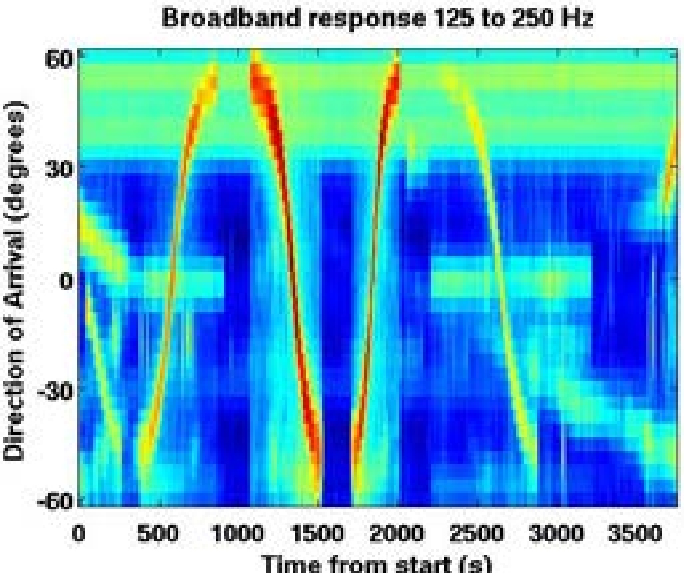
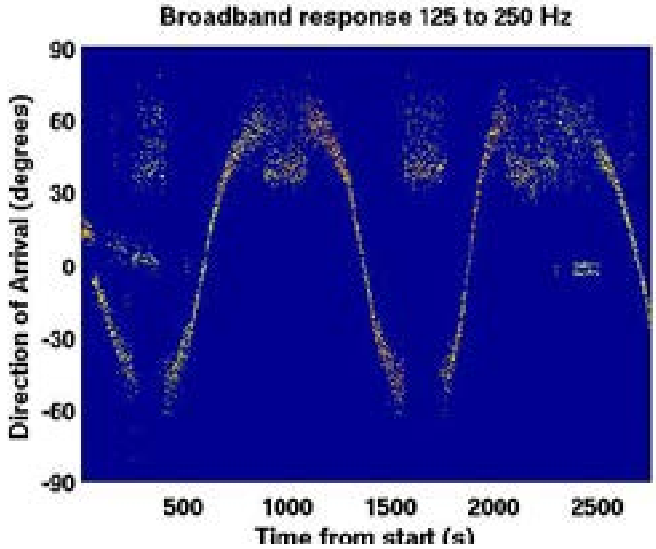
Results

The method of robust de-noising and DOA estimation is evaluated on a dataset acquired in Portland harbour, UK. The results of using traditional beamforming techniques are shown below (left) together with the results of our proposed method (right) are also shown and it can be seen that the target is accurately tracked whilst the amount of noise is greatly reduced.





References

[1] Mecklenbruker C, Gerstoft P, Panahi A, and Viberg M, "Sequential Bayesian sparse signal reconstruction using array data," IEEE Transactions on Signal Processing, vol. 61, no. 24, pp. 6344–6354, 2013.

[2] Barnard M, and Wang W, "Adaptive Bayesian sparse representation for underwater acoustic signal de-noising" In Proc. 2nd IET International Conference on Intelligent Signal Processing ISP 2015, London UK.