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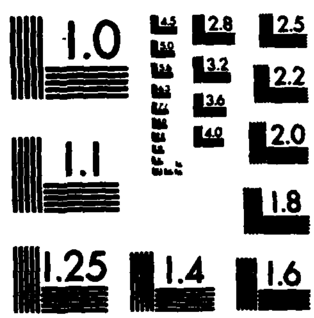

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COMPUTATIONALLY EFFICIENT ALGORITHMS FOR DETECTION AND ESTIMATION

FINAL REPORT

by:
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January 1983

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The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

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The focus of this research has been on adaptive and computationally efficient algorithms for multichannel signal detection problems with unknown second order statistics. The research goals here were to employ formal methods to obtain detection statistics, compute detection performance as summarized by receiver operating characteristics, and compare the results with current ad-hoc techniques. A secondary goal was to compare and contrast processor structures.

Three types of test statistics were compared on the basis of performance. These tests were a generalized likelihood ratio derived by a maximum likelihood technique, a Bayes test obtained by employing a conjugate (Inverted Wishart) prior density for the uncertain covariance matrix, and an estimate and plug test that was considered to be an example of current ad-hoc adaptive array processors. The performance calculations were based on both detailed analysis of the distributions of the tests and computer simulation. A simple form for the distribution of the generalized likelihood ratio was obtained, and it was shown that for a unique detection threshold, the detection performance of this test was exactly equal to that for the ad-hoc estimate and plug test. For other thresholds, the ad-hoc test was less powerful, with the degree of relative degradation dependent on system parameters such as detection length and signal to noise ratio. In all but the degenerate situation where prior knowledge of the covariance matrix was allowed to completely dominate the data, the Bayes test effectively and safely improved detection performance over that of the previously mentioned tests. A major conclusion of this study was that such improvement could be obtained with little risk, ..e., the prior knowledge for the covariance matrix did not have to be specified very accurately.

1.0 STATEMENT OF THE PROBLEM

The problem is to develop improved multichannel signal processing techniques for the detection and estimation of signals in noise, especially for situations in which the second order statistics of the signal and/or the noise are initially uncertain. This information must be obtained in large part from the data itself along with the use of some a priori knowledge. Improved signal processing techniques are needed in a variety of areas including communications, surveillance, noise cancellation, spectral analysis, adaptive line enhancement, seismics, direction finding, and antenna beamforming. Emphasis is to be placed on developing algorithms that are adaptive to the signal and noise environment, have good performance, and that are computationally efficient.

2.0 SUMMARY OF RESULTS

The focus of this research has been on adaptive and computationally efficient algorithms for multichannel signal detection problems with unknown second order statistics. These types of situations are broadly applicable to physical problems in a variety of areas. Much of this research has been motivated by problems that are now being solved by informal "adaptive array" methodologies. Adaptive arrays are to a great extent designed for situations where the data to be processed has second order statistics that are unknown a priori; the processing goal is to obtain a least squares estimate of a desired component of the input, or in a detection framework to maximize signal to noise ratios so as to minimize the probability of detection error. The research goals here were to employ formal methods to obtain detection statistics, compute detection performance as summarized by receiver operating characteristics, and compare the results with current ad-hoc techniques. A secondary goal was to compare and contrast processor structures.

Three types of test statistics were compared on the basis of performance. These tests were a generalized likelihood ratio derived by a maximum likelihood technique, a Bayes test obtained by employing a conjugate (Inverted Wishart) prior density for the uncertain covariance matrix, and an estimate and plug test that was considered to be an example of current ad-hoc adaptive array processors. The performance calculations were based on both detailed analysis of the distributions of the tests and computer simulation. A simple form for the distribution of the generalized likelihood ratio was obtained, and it was shown that for a unique detection threshold, the detection performance of this test was exactly equal to that for the ad-hoc estimate and plug test. For other thresholds, the ad-hoc test was less powerful, with the degree of relative degradation dependent on system parameters such as detection length and signal to noise ratio. In all but the degenerate situation where prior knowledge of the covariance matrix was allowed to completely dominate the data, the Bayes test effectively and safely improved detection performance over that of the previously mentioned tests. A major conclusion of this study was that such improvement could be obtained with little risk, i.e., the prior knowledge for the covariance matrix did not have to be specified very accurately.

Results were also obtained by considering various implementations of the tests. It was shown that iterative methods could be used to develop the required weighting vectors to form the tests. The resulting algorithm was, however, more complicated than current algorithms such as the LMS algorithm, a matrix operator being substituted for an ordinary feedback gain. Connections were made between the problem under consideration and regression (correlation) models, establishing the indirect applicability of the vast literature on this subject. It was of some interest to note that the Bayes test could be viewed as employing ridge-regression estimates of the optimal adaptive weights while the generalized likelihood ratio used ordinary least squares estimates of these quantities.

It should be emphasized that the results that were obtained were of a general nature; no specific assumptions were made about the number of array channels to be used, the nature of the covariance matrix, or the detection length. Every attempt was made to explore the fundamental nature of the problem as described. It is therefore thought that the results are applicable to a broad category of physical models. In the case of the Bayes test, examples were used to illustrate methods for an appropriate assignment of prior probabilities so that the mathematics involved in the method would not obscure its utility for the practicing engineer.

3.0 PUBLICATIONS

Detection of Known Signals in Noise of Uncertain Covariance - A Comparative Study, S. L. Earp, Masters Thesis, Department of Electrical Engineering, Duke University, Durham, NC, July 1982. Also Technical Report No. 18.

4.0 SCIENTIFIC PERSONNEL

Scientific personnel on this project were Mr. S. L. Earp and Prof. L. W. Nolte.

Mr. S. L. Earp obtained his MSE while working on this research project at Duke University in July 1982.