REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
06-10/98

3. REPORT TYPE AND DATES COVERED
ANNUAL 06-01-97 through 05-31-98

4. TITLE AND SUBTITLE
DISTRIBUTED SENSOR FUSION BASED ON STATISTICAL INFERENCE

5. FUNDING NUMBERS
CONTRACT
N00014-97-1-0917

6. AUTHOR(S)
RAMANARAYANAN VISWANATHAN

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
ELECTRICAL ENGINEERING DEPARTMENT
SOUTHERN ILLINOIS UNIVERSITY AT CARBONDALE
CARBONDALE, IL 62901-6603

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
OFFICE OF NAVAL RESEARCH
BAALLSTON TOWER ONE
800 NORTH QUINCY STREET
ARLINGTON, VA 22217-5660

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

In the twelve month period between June 1997 and May 1998, we have looked into two problems related to data fusion from multiple sensors. The first deals with the distributed constant false alarm rate radar target detection and the other examines a rank based test for M-ary detection problem. The rank based test was also applied to diversity combining of antenna array signals in a wireless DS/CDMA system.

19980617 015

14. SUBJECT TERMS
DISTRIBUTED CFAR TESTS, RANK TESTS, DIVERSITY COMBINING

15. NUMBER OF PAGES
3

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT

18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

Annual Report on the Contract- N00014-97-1-0917

Title **Distributed Sensor Fusion Based on Statistical Inference**

PI **Ramanarayanan Viswanathan**

In the twelve month period between June 1997 and May 1998 we have looked into two problems related to data fusion from multiple sensors. The first deals with the distributed constant false alarm rate radar target detection and the other examines a rank based test for M-ary detection problem.

We have evaluated the performances of several distributed CFAR tests operating in different background clutter conditions[1-5]. The analysis considers the detection of Rayleigh target in various clutters with the possibility of differing clutter power levels in the test cells of distributed radars. Numerical results studied for a two radar system show how the false alarm rate of the maximum order statistic (MOS) test changes with differences in the clutter power levels of the test cells. The analysis for the detection of Rayleigh target in Rayleigh clutter indicates that, with differing clutter cells' power levels, the OR fusion rule can be quite competitive with the new normalized test statistic (NTS). However, for the detection of Rayleigh target in Weibull or K- distributed clutter, the results show that NTS outperforms both the OR and the AND rules under the condition of large signal to clutter power ratio and moderate shape parameter values.

We examined a rank order based test for a general M-ary communication problem, which is stated as follows: Given M groups of L samples each, the problem is to identify which unique group of L samples have come from the signal hypothesis. The optimal likelihood ratio test that minimizes the probability of incorrect classification can be constructed if the joint distribution of these ML samples is completely known. However, in many cases, the distribution is either unknown or only known partially. Therefore, suboptimal tests, such as tests based on rank orders, can be considered. By considering the observations as a matrix of M rows with L columns, a rank matrix is created by rank ordering these observations and then replacing the samples with their corresponding ranks. Then a *Rank Sum Test* declares the row with the maximum rank sum as the row corresponding to the signal hypothesis. Since ranking ML samples might take considerable amount of time, a *Reduced Rank Sum Test* (RRST) rank orders the samples in each column separately into values of 1 through M, and then picks the row with the maximum rank sum. A variation of the RRST is to create a value matrix where the (i,j) element of the value matrix is either equal to the (i,j) element of the rank matrix, if the rank exceeds a threshold M-p+1, or is equal to zero. The *Modified Rank Test* (MRT) then picks the row with the maximum sum of values. If p=1, the MRT retains only the maximum rank of M in each column and assigns zero values to the others. In other words, independently for each column, the row with the largest rank is decided as the signal row. Therefore, for p=1, MRT can be thought of as a majority logic combining of the decisions made in each column. For other values of p, MRT can be thought of as combining decisions, when decisions are presented with confidence weights[6]. Another variation of MRT is obtained by first sorting out elements in each row according to their values before performing the reduced ranking and clipping operations. We call such a procedure as row sorted MRT. What row sorting does is to produce comparison of weakest signal against weakest interference (plus noise), comaprison of the next weakest signal against the next weakest interference, and so on. Through simulation studies we have found that row sorting produces significant reduction in error rates in a number of constant signal-in-noise detection problems involving Gaussian, Laplace and exponential distributions. Certainly, for low p values, the row sorting reduces the error rate of simple MRT by an order of magnitude. The results from this study will be submitted for publications shortly.

Encouraged by these results we examined the applicability of MRT to diversity combining of antenna array signals in a wireless DS/CDMA system. The performances of equal gain combining (EGC), likelihood ratio test (LRT) and the MRT were evaluated using simulation studies[7,8]. The results indicate that, under certain assumptions on the multiple access interference statistics, the probability of error of MRT(row sorted) is lower than that of EGC, if a few high power interfering users are present along with a low power user of interest. If there are a moderately large number of users and if the received powers of all the users are nearly the same, then EGC outperforms MRT. In fact, under this condition, the performance of EGC is close to that of the optimal likelihood ratio test. We are continuing the evaluation of MRT under different interference situations. Also, the usefulness of MRT in combating partial band jammers in frequency hopping systems is being examined.

Publications

1. C.H. Gowda, M.K. Uner, P.K. Varshney and R. Viswanathan, "Distributed CFAR Target Detection," to appear in the *Journal of Franklin Institute*, 1998.

2 C.H. Gowda and R. Viswanathan, "Performances of Distributed CFAR Tests in Nonhomogeneous Background," *Proceedings of the National Radar Conference*, Syracuse, NY., 1997, pp. 36-41.

3. C.H. Gowda and R. Viswanathan, "Distributed Detection of Rayleigh Target in Weibull Clutter," to appear in the *Proceedings of CISS*, Department of Electrical Engineering, Princeton University, Princeton, NJ., 1998.

4. C.H. Gowda and R. Viswanathan, "Distributed Detection of Rayleigh Target in K-Distributed Clutter," *Proceedings of SPIE*, Sensor Fusion: Architectures, Algorithms, and Applications II, Orlando, FL, 1998, pp. 175-185.

5. C.H. Gowda and R. Viswanathan, "Performance of Distributed CFAR Tests Under Various Clutter Amplitudes," submitted to *IEEE Transactions on AES*, May 1998.

6. V. Annampedu and R. Viswanathan, "A Rank Order Test for M-ary Detection," *Proceedings of the Conference on Information Sciences and Systems*, Department of Electrical Engineering, Johns Hopkins University, March 1997, pp. 819-824.

7. C.H. Gowda, V. Annampedu, and R. Viswanathan, "Diversity Combining in Antenna Array Base Station Receiver for DS/CDMA," to appear in the *IEEE Communications Letters*, July 1998.

8. C.H. Gowda, V. Annampedu, and R. Viswanathan, "Diversity Combining in Antenna Array Base Station Receiver for DS/CDMA,"to be presented and published in *International Conference on Communications*, Atlanta, GA, June 1998.