UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A257 483

(12)

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for Public Release: Distribution Unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: Department of Statistics; 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State and ZIP Code): University of North Carolina, Chapel Hill, North Carolina 27514	7b. ADDRESS (City, State and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Office of Naval Research; 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: N00014-89-J-1175
8c. ADDRESS (City, State and ZIP Code): Mathematical Sciences Division, Arlington, VA 22217-5000	10. SOURCE OF FUNDING NOS.
11. TITLE (Include Security Classification)	

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.

12. PERSONAL AUTHOR(S) C.R. Baker

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
FINAL TECHNICAL	FROM 11/1/88 TO 6/30/92	Sept. 30, 1992	8

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

DTIC ELECTE NOV 19 1992 S B D

182850

92-29837

9 9

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED XX SAME AS RPT. XX DTIC USERS ☐

21. ABSTRACT SECURITY CLASSIFICATION

22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL
C.R. Baker	(919) 962-2189	

DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

FINAL TECHNICAL REPORT

for

INFORMATION AND STOCHASTIC SYSTEMS

ONR CONTRACT N00014-89-J-1175

01 November 1988 - 30 June 1992

Charles R. Baker

Department of Statistics

University of North Carolina at Chapel Hill

Chapel Hill, North Carolina 27599-3260

September 30, 1992

SUMMARY

Principal results obtained during the contract period were in the following areas:

1) Information capacity of stationary Gaussian channels;

2) Information capacity of Gaussian channels subject to jamming;

3) Capacity of Poisson and Poisson-related channels;

4) Coding capacity of dimension-limited channels;

5) Absolute continuity and channel capacity for problems involving Gaussian-mixture noise;

6) Further development of new algorithms for signal detection;

7) Computational evaluation of both new and classical algorithms for detection of signals in noise, with comparisons and results;

8) Analysis and modeling of passive sonar data;

9) Representation of stochastic processes.

Two of the PI's students received the Ph.D. in Statistics during this period; both were supported in part by grant funds. In addition, five other graduate students received some financial support from the grant, primarily for work associated with the computational work on tasks 7) and 8) above.

As can be seen from the above list of topics, and more clearly from the remaining parts of this report, the principal thrust of the research carried out under the grant has been on capacity of noisy communication channels and on nonGaussian signal detection problems. Our work has differed from all other work known to us in two respects:

a) For channel capacity, our emphasis is on general continuous-time channels or infinite-dimensional discrete-time channels;

b) For signal detection, we emphasize a rigorous mathematical solution of the underlying continuous-time problem, develop discrete-time algorithms based on those solutions, then computationally evaluate the algorithms using both simulated data and experimental data obtained from operational systems.

So far as we know, all work published during the past 15 years in these two areas which has all of the above characteristics has emanated from our research program. This includes work not only by the PI, but by his students and by a number of colleagues in Japan and Europe. The research supported by this grant has continued the previous work, and the continuity of funding provided by ONR has been extremely important in enabling us to obtain the results described below.

The results in each of the nine areas listed above are very briefly described in the next section.

DISCUSSION OF MAIN RESULTS

1. Information Capacity of Stationary Gaussian Channels [15].

This is one of the principal areas of research in the Shannon theory. A partial solution was obtained in [1]. The solution obtained in our work [15] is far more general. For Gaussian channels having noise with rational spectral densities, our results provide a complete solution to the information capacity problem. This includes an independent proof of the results of [1] for noise having a rational spectral density.

2. Information Capacity of Gaussian Channels Subject to Jamming [8], [9].

The channels considered in this work are "matched"; in the absence of jamming, the constraint on the transmitted signal is given in terms of the noise covariance. Our interest is primarily in channels with memory, especially infinite-dimensional channels (e.g., continuous-time channels with memory).

One result obtained in this work is that use of a jammer constraint commonly employed in engineering analysis of finite-dimensional channels is too strong to be meaningful when used for the infinite-dimensional channel: the jammer cannot decrease the capacity of the channel, regardless of his available energy. A more realistic constraint on the jammer was determined, and, as this constraint was not previously applied in previous published work, the jamming problem was solved for both finite-dimensional and infinite-dimensional channels.

3. Capacity of Poisson and Poisson-Related Channels [11], [16].

Poisson channels are of particular interest in optical communications. The continuous-time problem was modeled and the information capacity obtained for the case of random or time-varying noise intensity. Bounds were obtained on the increase in capacity obtained with causal feedback. A class of jamming problems was considered, and the optimal jamming signal determined. Results on coding capacity were obtained. The results given in [16] provide a compact unification of several seemingly-disparate results on capacity.

4. Coding Capacity of Dimension-Limited Additive Channels [10], [13].

This work applies to communication channels where the dimensionality of the code word set is a part of the signal constraint. A complete solution of the coding capacity problem was obtained for Gaussian channels, and upper bounds on capacity for a class of nonGaussian channels. These results contain, as special cases, solutions to coding capacity for the classical discrete-time Gaussian channel, and coding capacity for a class of continuous-time Gaussian channels.

5. Absolute Continuity and Channel Capacity for Problems involving Gaussian-Mixture Noise [17], [18].

Gaussian-mixture noise is of the form N = AG, where G is a Gaussian process and A is a non-negative random variable independent of G. Such a process is frequently used to model noise arising in sonar applications. In [17], the absolute continuity problem is considered: conditions for the likelihood ratio to exist between a process Y (e.g., signal-plus-noise) and a Gaussian mixture noise process N. A solution is obtained, and expressions for the likelihood ratio obtained. These results are then applied to obtain the information capacity of a communication channel perturbed by additive Gaussian mixture noise.

6. Further Development of New Algorithms for Signal Detection [14], [18].

This work was based on the mathematical results contained in [2] and [17]. A preliminary description of the algorithms for detection in Gaussian noise was given in [3]. The treatment in [18] is far more complete and includes several new results. These include, for example, algorithms for detection in Gaussian-mixture noise.

The 49-page paper [18] was solicited in 1989 for inclusion in a book to be published in 1990. The latest estimate is that the book will be published in 1993. One of the editors of this book has been Principal Investigator of an SBIR contract on detection of nonGaussian signals in Gaussian noise (the Phase II contract now being in progress). He has commented to the PI that the development in [18] was viewed as "the most promising" approach, based on his company's Phase I survey of applicable methods. The Phase II contract is apparently an extension to arrays of the computational evaluations described in [14].

7. Computational Evaluation of both New and Classical Algorithms for Signal Detection [14].

This work involved the use of simulated data and passive sonar data. The primary objective was to obtain numerical results on performance of new algorithms described in [18] and [3], and to compare this performance with that of selected reference algorithms. In short, the new algorithms gave very good relative performance. The relative performance should increase with more realistic data sets and with progress on optimizing their parameters.

8. Analysis and Modeling of Passive Sonar Data [6], [20].

This work involved statistical testing of the passive sonar data used to carry out the evaluations described under (7) above. It was found that neither the noise nor the signal-plus-noise could be clearly accepted as Gaussian, although the degree of non-normality varied with the frequency range.

Another element of this work was the modeling of the data as a Gaussian mixture. This aspect appears to have some potential for use in classification.

This work was an extension and refinement of earlier work, reported in [20].

9. Representation of Stochastic Processes [12], [19].

The mathematical results obtained in [2], which have provided the theoretical foundation for the promising new algorithms described in [3] and [18], are based on the spectral representation of second-order stochastic processes, and also make use of reproducing kernel Hilbert space (RKHS) theory at key points of the development.

The technical reports [12] and [19] contain a development of the applicable theory in these two areas. The RKHS report is directed toward readers interested in stochastic processes.

REFERENCES

1. R.G. Gallager, *Information and Reliable Communication*, Wiley, New York (1966).

2. C.R. Baker and A.F. Gualtierotti, Discrimination with respect to a Gaussian process, *Probab. Theory and Rel. Fields, 71* , 159-182 (1986).

3. ______________________________, Likelihood ratios and signal detection for nonGaussian processes, *Stochastic Processes in Underwater Acoustics* , Lecture Notes in Control and Information Science, Springer-Verlag, 85, 154-180, Berlin (1986).

4. __________ and I.F. Chao, Information capacity of additive Gaussian channels with jamming, *Proc. 22nd Conf. on Information Science and Systems*, Johns Hopkins University, 52-55 (1989).

5. __________, A.F. Gualtierotti and M.R. Frey, Some results on nonGaussian signal detection, *Proc. 12th Colloque sur le traitment du signal et ses applications*, 115-118, GRETSI (1989).

6. C.R. Baker, M.R. Frey, S.T. Garren, R. Lund and P.L. Seymour, Signal detection and data analysis/modeling: A computational study, (November 1989).

7. C.R. Baker, Capacity of a class of additive dimension-limited channels, *Proc. Allerton Conf. on Communications, Computing, and Control*, University of Illinois, 1103-1111 (1989).

8. ______________________, Information capacity of the matched Gaussian channel with jamming, II. Infinite-dimensional channels, LISS-47 (October 1990).

9. __________ and I.F. Chao, Information capacity of the matched Gaussian channel with jamming, I. Finite-dimensional channels, LISS-34 (November 1990).

10. C.R. Baker, Coding capacity for a class of additive channels, *IEEE Trans. on Information Theory*, IT-37, 233-243 (1991).

11. M.R. Frey, Information capacity of the Poisson channel," *IEEE Trans. on Information Theory*, 37, 244-256 (March 1991).

12. C.R. Baker, Spectral multiplicity for second-order stochastic processes, LISS-49 (March 1991).

13. C.R. Baker, Capacity of dimension-limited channels, *J. Multivariate. Anal.*, 37, 239-258 (1991)

14. __________, M.R. Frey and C.E. Persons, A computational evaluation of new detection algorithms, *U.S. Navy J. of Underwater Acoustics*, 37, 457-476 (1991).

15. __________ and S. Ihara, Capacity of the stationary Gaussian channel, *IEEE Trans. on Information Theory*, 37, 1314-1326 (1991).

16. M.R. Frey, Capacity of the L_p-norm-constrained Poisson channel, *IEEE Trans. on Information Theory*, 38, 445-450 (1992).

17. __________ and A.F. Gualtierotti, Absolute continuity and mutual information for Gaussian mixtures, *Stochastics and Stochastic Reports*, 39, 139-157 (1992).

18. __________ and A.F. Gualtierotti, Likelihood-ratio detection of stochastic signals, to appear, *Advances in Statistical Signal Processing. Volume 2: Signal Detection*, H.V. Poor and J.B. Thomas, eds., JAI Press. Also LISS-40 (October 1989).

19. __________, Reproducing kernel Hilbert spaces, preprint (July 1992).

20. __________, H. Cherifi, T.G. Dankel, and M.R. Frey, Analysis, modeling, and signal detection for a set of passive sonar data, LISS-50 (August 1992).

NOTE: LISS = Laboratory for Information and Stochastic Systems, Department of Statistics, University of North Carolina, Chapel Hill, NC 27599-3260.