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FINAL SCIENTIFIC REPORT
to
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

on

ROBUST PROCEDURES FOR COMMUNICATION DATA

Presented by:

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

Work on the following topics is summarized:

1. The qualitative theory of robustness in parameter estimation, as initiated by Hampel' and extended by the author, was modified and extended to include robust filtering. The qualitative properties of robust filters have been studied and analyzed. 2. The qualitative analysis of robust filtering and smoothing provides some specific sufficient conditions regarding the filtering and smoothing operations. In particular, a nonlinear such operation is included. 3. The investigators have studied robust linear prediction and interpolation for convex and compact families of vector stationary processes. They have formalized the problem as a stochastic game with saddle point solution, and have found this solution for a number of processes families. Such families include the family of linearly contaminated nominal processes, and the class of processes whose total energy is fixed within prespecified quantiles. (CONTINUED)

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ITEM #19, CONTINUED: 4. The investigators have formalized, solved, and analyzed robust linear filtering for convex and compact families of vector stationary information and noise processes. They have found the robust solutions for various such families, and have studied their performance both analytically and numerically, in terms of efficiency, performance deviation, and breakdown points or curves. 5. The investigators examined the properties of two-dimensional random processes as applied to imaging. 6. The investigators have considered the multiple-access problem, where a finite number of packet-transmitting data users access a single channel while they sense the feedback only whenever blocked. They designed and fully analyzed a random-access, collision-resolution protocol for this case.

A. SUMMARY OF ACCOMPLISHED WORK

The summary of the work accomplished in the approximate period of July 1, 1982 to August 31, 1983 is summarized below. The details of the work has been submitted to the AFOSR in the form of reports (see part B of this report under University reports).

1. The qualitative theory of robustness in parameter estimation, as initiated by Hampel and extended by the author of this proposal for stationary observations with memory, was modified and extended to include robust filtering. The qualitative properties of robust filters have been studied and analyzed. These properties include specific nonlinear operations that can be used as design guidelines. The robust filters for some specific convex classes of stationary processes and noise channels have been designed and fully analyzed.

2. The qualitative analysis of robust filtering and smoothing provides some specific sufficient conditions regarding the filtering and smoothing operations. In particular, a nonlinear such operation is included. Adopting the mean-squared performance criterion and for convex and compact families of stationary processes, we developed a class of lower bounds on the performance of robust filters and smoothers. Those bounds apply for a whole class of nonlinear filtering and smoothing operations, and they can be used as evaluation measures in the design of robust filters and smoothers.

3. We have studied robust linear prediction and interpolation for convex and compact families of vector stationary processes. We have formalized the problem as a stochastic game with saddle point solution, and we have found this solution for a number of processes families. Such families

include the family of linearly contaminated nominal processes, and the class of processes whose total energy is fixed within prespecified quantiles.

4. We have formalized, solved, and analyzed robust linear filtering for convex and compact families of vector stationary information and noise processes. We have found the robust solutions for various such families, and we have studied their performance both analytically and numerically, in terms of efficiency, performance deviation, and breakdown points or curves.

5. We examined the properties of two-dimensional random processes as applied to imaging. We demonstrated that image filtering, restoration, representation, discrimination between images, and statistical inference of the image models, can be performed efficiently and without the need for approximations, in the discrete Fourier domain. We considered periodic random process models in our demonstration. Those models are generalizations of image models previously considered by other investigators.

6. We have considered the multiple-access problem, where a finite number of packet-transmitting data users access a single channel while they sense the feedback only whenever blocked. We designed and fully analyzed a random-access, collision-resolution protocol for this case. We compared the throughput and the delays induced by this protocol with those induced by previously proposed protocols. We found that the performance of the new protocol is superior.

B. PUBLICATIONS SUPPORTED

Papers Submitted to Journals

1. P. Papantoni-Kazakos, "A Game Theoretic Approach to Robust Filtering,"
2. P. Papantoni-Kazakos, "Performance Bounds in Robust Filtering and Smoothing,"
3. H. Tsaknakis, D. Kazakos, and P. Papantoni-Kazakos, "Robust Prediction and Interpolation for Vector Stationary Processes,"
4. H. Tsaknakis and P. Papantoni-Kazakos, "Robust Linear Filtering for Multivariable Stationary Series,"
5. P. Papantoni-Kazakos, G. D. Marcus, and M. Georgiopoulos, "A Collision Resolution Protocol with Limited Channel Sensing-Finitely Many Users,"
6. R. K. Bansal and P. Papantoni-Kazakos, "An Algorithm for Detecting a Change in Stochastic Process,"

Conference Presentations - Proceedings

1. D. Kazakos and P. Papantoni-Kazakos, "Periodic Random Processes as Models for Two-Dimensional Signals and Images," IEEE MELECOM' 83, May, 1983.
2. H. Tsaknakis, P. Papantoni-Kazakos, and D. Kazakos, "New Results on Robust Estimation on Multivariable Stationary Random Processes," 1983 Conference on Information Sciences and Systems, Johns Hopkins University.
3. P. Papantoni-Kazakos, "Performance Bounds in Robust Filtering and Smoothing," 1983 International Symposium on Information Theory, Montreal, Canada.
4. H. Tsaknakis, D. Kazakos, and P. Papantoni-Kazakos, "Robust Prediction and Interpolation for Vector Stationary Processes," 1983 International Symposium on Information Theory, Montreal, Canada.

Book Chapters

1. D. Kazakos and P. Papantoni-Kazakos, "Modeling of Multidimensional Signals with Applications to Images," in Multidimensional Systems Theory, Marcel Dekker, N.Y., in printing.
2. P. Papantoni-Kazakos, "Qualitative Robustness in Time Series Analysis," Results on the 1983 workshop on Rcbust and Nonlinear Methods in Time Series Analysis, Springer-Verlag Heidelberg, Germany, to appear in 1984.

University Reports Submitted to the Air Force

1. P. Papantoni-Kazakos, "Performance Bounds in Robust Filtering and Smoothing," EECS Dept., University of Connecticut, TR-82-6, October, 1982.
2. H. Tsaknakis, D. Kazakos, and P. Papantoni-Kazakos, "Robust Prediction and Interpolation for Vector Stationary Processes," EECS Dept., University of Connecticut, TR-82-7, November, 1982.
3. P. Papantoni-Kazakos, G. D. Marcus, and M. Georgiopoulos, "A Collision Resolution Protocol with Limited Channel Sensing - Finitely Many Users," EECS Dept., University of Connecticut, TR-83-2, February 1983.
4. H. Tsaknakis and P. Papantoni-Kazakos, "Robust Linear Filtering for Multivariate Stationary Time Series," EECS Dept., University of Connecticut, TR-83-6, Spring, 1983.
5. R. K. Bansal and P. Papantoni-Kazakos, "An Algorithm for Detecting a Change in Stochastic Process," EECS Dept., University of Connecticut, UCT/DEECS/TR-83-7, June, 1983.
6. H. Tsaknakis, D. Kazakos and P. Papantoni-Kazakos, "Robust Prediction and Interpolation for Vector Stationary Processes-2d Enriched Version," EECS Dept., University of Connecticut, UCT/DEECS/TR-83-10, July, 1983.
7. H. Tsaknakis and P. Papantoni-Kazakos, "Robust Linear Filtering for Multivariable Stationary Time Series-2d Enriched Version," EECS Dept., University of Connecticut, UCT/DEECS/TR-83-9, July, 1983.

Special Activities

1. Dr. Papantoni-Kazakos spent the time period from August 2, 1983 to August 9, 1983, in intensive interaction with an international group of statisticians working on Robust Statistics, at the University of Washington, Seattle, department of Statistics. The group included:

D. Cox (Univ. of Wisconsin), D. R. Martin (Univ. of Washington), V. Yohai (Univ. of Buenos Aires, Argentina), and P. J. Rousseeuw (Univ. of Brussels, Belgium).

2. Dr. Papantoni-Kazakos will participate in the 1983 workshop on Robust and Nonlinear Methods in Time Series Analysis, Heidelberg, Germany, Sept. 26, 1983 to Sept. 30, 1983.