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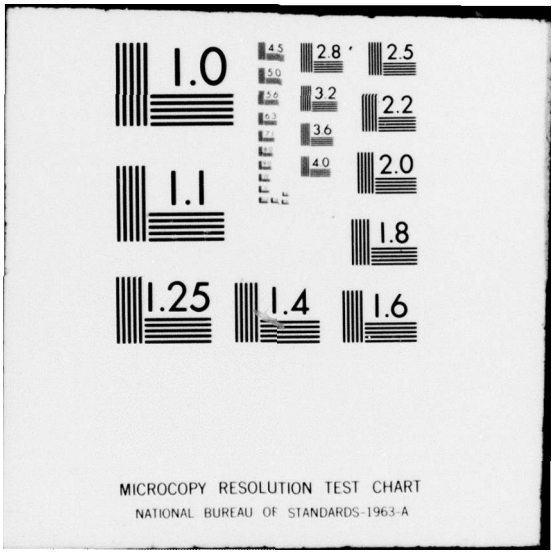
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report provides a summary of the research accomplishments in the areas of digital filter design, digital signal processing, and digital system optimization, speech analysis and synthesis, algorithm complexity, and picture and two-dimensional processing. The report also lists 68 publications.

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Digital Signal Processing

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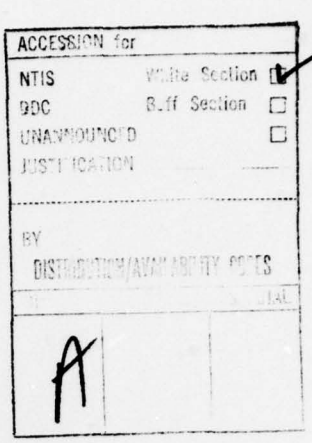

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1. Summary of Research Accomplishments

Virtually all of the important research results obtained during execution of the referenced grant were reported in journal articles and conference papers, and these are listed in Section 3. We give here brief summaries of the major contributions; reference numbers are to Section 3.

A. Digital Filter Design ([4,39,61])

In [4] an effective heuristic is described for the difficult problem of section-ordering to reduce roundoff noise accumulation in cascade realizations of IIR digital filters. In [39] an efficient method is described for generating samples of certain waveforms without the aliasing effect. In [61] a method is described for using linear programming to design FIR digital filters with constraints on the derivative of the frequency response, as well as the magnitude. This yields designs which have flat passbands and are optimal in the minimax sense - the digital equivalent of the type II Chebyshev analog filters.

B. Digital Signal Processing and Digital System Optimization ([5-7],[14-22],[26-28],[33-38],[47-53],[57-60],[63-68])

A wide spectrum of problems have been attacked involving the processing of digital signals and/or the design of optimal digital systems. Loosely speaking, most of the problems worked on can be divided into two categories: (a) Properties of Random Processes and Sequences and (b) Detection, Estimation, and Extraction of Digital Signals from Noise.

(a) Properties of Random Processes and Sequences - In an attempt to circumvent the usual assumption of independence in processing

data sequences, we have continued studies along several lines. We have made significant progress in bivariate distribution representation, characterization, and application [5,18,48,], allowing us to take into account the dependency relationship between adjacent data points. We have developed a generalized shot process model [15] for noise and have found it applicable as a stochastic model for such diverse situations as coronas from HV transmission lines [16], lightning discharges [22], the power spectral densities of modulated error-correcting codes [17], and the synthesis of block codes in PAM [63]. In a more general and somewhat more theoretical setting, we have studied the structure and representation of nonstationary [21,28] and non-Gaussian [59] processes with the aim of producing more realistic noise models for real-life situations.

(b) Detection, Estimation, and Extraction of Digital Signals from Noise - Most of this work has been aimed at the development of new and less-restrictive optimal systems than specified by classical parametric techniques. We have continued an extensive study of nonparametric techniques [6,33,36] including the difficult problem of sample dependence. Closely related studies have been made of conditional tests [14,26,66] and of the general problem of optimal signal quantization [7,47,53,60]. With respect to the latter problem, we have developed some interesting results for m-dependent noise [34,68] and for noise modelled as an impulsive mixture [27]. To avoid problems associated with some of the classical techniques, we have applied maximum distance [64] and locally optimal [57,65] criteria. We have begun an extensive study of sequential techniques [20,37] with a view to exploiting their

superior efficiency. We have continued work on robust systems both in references [38,51,67] and in other parts of this work as referenced elsewhere. Finally, we have made some investigation of arrays for data processing [19].

In our study of optimal and robust systems, we have been lead to look at quasi-optimal systems [35,50,58] which are inherently simpler and more robust by almost any criterion when compared to appropriate optimal systems. This work has been enlightening and useful but we feel that a great deal remains to do - particularly in view of the difficulty in defining precisely such problems.

As an off-shoot of our other work, we have investigated the problem of minimizing intersymbol interference in data communication systems when a considerable amount of noise is present [49,52].

C. Speech Analysis and Synthesis ([1,2,8,23,29,30,43,44,62])

Items [8,62] describe the use of pattern classification ideas to make the voiced/unvoiced decision in speech - one of the most important and troublesome problems in an effective analysis-synthesis system. Items [23,29,30,43,44] are concerned with the problem of pole-zero modeling of signals. This is a general signal modeling problem of importance in other areas, such as system identification and geophysical data processing. Items [1,2] describe a new method for generating speech-like signals with very simple hardware.

D. Algorithm Complexity [3,9-13,24,25,31,32,45,46,55]

Items [3,9-13,24,25] report results concerning intractible problems. They show for the first time that certain interesting problems belong to the NP-complete class, and give difficult

instances of the famous traveling salesman problem. Item [31] gives an O(nlogn) algorithm for finding the error of approximation of a signal by trigonometric polynomials. Item [46] gives new asymptotically-fast algorithms for the partial fraction expansion problem and its inverse. Items [45,55] concern the design of networks with small diameter, which may be useful for interconnecting microprocessors. Item [32] shows that a proposed class of pathological linear programs proposed by N. Zadeh are not robust under random permutations of the columns.

E. Picture and Two-Dimensional Processing ([40-42,54,56])

This work is concerned with the effective use of tree structures to represent pictures. Asymptotically fast algorithms are presented for building quad-trees for polygons, for coloring their interiors, and for superposing, intersecting, translating, and rotating pictures represented by such trees.

2. Participating Personnel

2.A Faculty Supported by this Contract:

J.B. Thomas (Principal Investigator)
K. Steiglitz (Principal Investigator)

2.B Graduate Students Supported or Partially Supported by this Contract:

R. Ansari	W.P. Niedringhaus
M. Bateman	H.V. Poor
E. Coyle	F. Sadri
J. Feingold	J. Stolz
J. Gilchrist	S. Tantaratana
G. Hunter	S. Toueg
S.A. Kassam	M. Yannakakis

2.C Graduate Students Supported by Departmental or other Means During Period Covered by this Report:

J.S. Abrahams	D. Tjostheim
F.Y. Chin	S. Tyan
Y.C. Jenq	G.L. Wise
C.H. Papadimitriou	M.D. Wood
L. Seigel	

2.D Ph.D. Dissertations Completed:

S.A. Kassam: "Nonparametric and Robust Detection," August 1975.

F.Y.-L. Chin: "Complexity of Numerical Algorithms for Polynomials," October 1975.

C.H. Papadimitriou: "The Complexity of Combinatorial Optimization Problems," August 1976.

Y.C. Jenq: "Analysis and Design of Digital Data Transmission Systems," August 1976.

S. Tantaratana: "On the Relative Efficiencies of Some Parametric and Nonparametric Sequential Detectors, April 1977.

H.V. Poor: "Topics in Optimal and Robust Detection," April 1977

L.J. Siegel: "A Pattern Classification Algorithm for the Voiced/Unvoiced Decision in Speech Analysis," May 1977.

G. Hunter: "Efficient Computation and Data Structures for Graphics," July 1978.

M.D. Wood: "Signal Detection in Correlated Noise," August 1978.

3. Publications (journal articles and conference papers including spillover from previous contract)

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2. _____, IEEE Trans. on Acoustics, Speech and Signal Processing, Vol. ASSP-24, No. 6, December 1976, pp.558-562.

3. "On the Complexity of Local Search for the Traveling Salesman Problem," C.H. Papadimitriou and K. Steiglitz, J. SIAM Computing, Vol. 6, No. 1, March 1977, pp.76-83.

4. "An Improved Algorithm for Ordering Poles and Zeros of Fixed Point Recursive Digital Filters," (correspondence) K. Steiglitz and B. Liu, IEEE Trans. on Acoustics, Speech and Signal Processing, Vol. ASSP-24, No. 4, August 1976, pp.341-343.

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9. "Some Complexity Results on the Traveling Salesman Problem," C.H. Papadimitriou and K. Steiglitz, Proc. 8th SIGACT Symposium on Theory of Computing, pp.1-9, Hershey, Pa., May 3-5, 1976.

10. "On the Complexity of the Local Structure of Certain Convex Polytopes," C.H. Papadimitriou, Proc. 1976 CISS Conference, pp.47-51, Johns Hopkins University, March 31-April 2, 1976.

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54. "Linear Transformation of Pictures Represented by Quad Trees," G.H. Hunter and K. Steiglitz, submitted for publication.

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