GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: June 21, 1976

Project Title: *Two-Dimensional Digital Signal Processing*

Project No: *E-21-683*

Project Director: *Dr. R. M. Mersereau & Dr. R. W. Schafer*

Sponsor: *U. S. Army Research Office, Research Triangle Park, NC*

Agreement Period: From *6/21/76* Until *6/20/79*

Type Agreement: *Grant No. DAAG29-76-G-0226*

Amount: *$49,455 ARO**
4,642 GIT (E-21-345)
$54,097 Total

**Incrementally funded; total estimated funding: $161,221*

Reports Required: *Progress Report*
Technical (When Justified)
Final Report

Sponsor Contact Person (s):

Technical Matters

Technology Division
U. S. Army Research Office
PO Box 1211
Research Triangle Park, NC

Contractual Matters
(thru OCA)

ONR RR
Georgia Institute of Technology

Defense Priority Rating:

Assigned to: *Electrical Engineering* (School/Laboratory)

COPIES TO:

- Project Director
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- Other _____

CA—3 (3/76)

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SPONSORED PROJECT TERMINATION

Date: 2/17/78

Project Title: Two-Dimensional Digital Signal Processing

Project No: E-21-683

Project Director: Dr. R.M. Mersereau and Dr. R.W. Schafer

Sponsor: U.S. Army Research Office; Research Triangle Park, NC 27709

Effective Termination Date: 1/14/78

Clearance of Accounting Charges: 1/14/78

Grant/Contract Closeout Actions Remaining:

_ Final Invoice and Closing Documents
X Final Fiscal Report and Closing Documents
_ Final Report of Inventions
X Govt. Property Inventory & Related Certificate
_ Classified Material Certificate
_ Other _____

NOTE: SEE E-21-B00

Assigned to: Electrical Engineering (School/Laboratory)

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Director, Physical Plant
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other _____

CA—4 (3/76)

E-21-683

PROGRESS REPORT

1. ARO PROPOSAL NUMBER: P-13761-EL

2. PERIOD COVERED BY REPORT: 6/21/76 - 12/31/76

3. TITLE OF PROPOSAL: Two Dimensional Digital Signal Processing

4. CONTRACT OR GRANT NUMBER: DAAG29-76-G-0226

5. NAME OF INSTITUTION: Georgia Institute of Technology

6. AUTHOR(S) OF REPORT: R. M. Mersereau and R. W. Schafer

7. LIST OF MANUSCRIPTS SUBMITTED OR PUBLISHED UNDER ARO SPONSORSHIP DURING THIS PERIOD, INCLUDING JOURNAL REFERENCES:

   None submitted during this period. Two papers recently submitted are attached.

8. SCIENTIFIC PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIS REPORTING PERIOD:

   R. M. Mersereau
   R. W. Schafer

13761EL

DR. R. M. MERSEREAU
DR. R. W. SCHAFER
GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL ENGINEERING
ATLANTA, GA 30332

BRIEF OUTLINE OF RESEARCH FINDINGS

During the preceding six months our work has focussed on the design of two-dimensional digital filters and on algorithms for deconvolution.

One research effort in filter design has been concerned with the application of a spectral factorization algorithm based upon the 2D-complex cepstrum to the factorization of two-dimensional magnitude squared functions obtained by McClellan transformations of one-dimensional magnitude squared functions.

Another approach to the design of 2D recursive digital filters involves the use of the 2D-complex cepstrum to obtain separable approximations to arbitrary filter characteristics. Separable filters are considerably easier to implement than non-separable ones. An algorithm has been developed and is being evaluated. This work is being done in collaboration with E. W. Kamen and A. M. Bush (also under ARO sponsorship).

Another area of concentration has been the investigation of algorithms for deconvolution. In particular, we have been concerned with signals that can be modelled as a sum of overlapping positive wavelets. Nonlinear modifications of a recently proposed linear iterative algorithm due to Prost and Goutte have produced extremely interesting results. Investigation of the properties of this class of algorithms is continuing. Applications to image enhancement appear to be promising.

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ATLANTA, GEORGIA 30332

TELEPHONE: (404) 894-2901

E-21-683

July 15, 1977

Mr. Richard O. Ulsh, Chief
Information Processing Office
U. S. Army Research Office
P. O. Box 12211, N. C. 27709

Dear Mr. Ulsh:

Enclosed is the semi-annual report for the half year ending June 30 for Grant Number DAAG29-76-G-0226. If we can provide further information, please contact us.

Thank you for your support of our work.

Sincerely yours,

Russell M. Mersereau
Assistant Professor

Ronald W. Schafer
Professor

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Enclosure

PROGRESS REPORT

1. ARO PROPOSAL NUMBER: P - 13761EL

2. PERIOD COVERED BY REPORT: January 1, 1977 - June 30, 1977

3. TITLE OF PROPOSAL: Two-Dimensional Digital Signal Processing

4. CONTRACT OR GRANT NUMBER: DAAG29-76-G-0226

5. NAME OF INSTITUTION: Georgia Institute of Technology

6. AUTHOR(S) OF REPORT: R. M. Mersereau and R. W. Schafer

7. LIST OF MANUSCRIPTS SUBMITTED OR PUBLISHED UNDER ARO SPONSORSHIP DURING THIS PERIOD, INCLUDING JOURNAL REFERENCES:

See Attached Sheet.

8. SCIENTIFIC PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIS REPORTING PERIOD:

R. M. Mersereau
R. W. Schafer
G. Shaw (Research Assistant)
G. Poe (Research Assistant)

13761EL

DR. R. M. MERSEREAU
DR. R. W. SCHAFER
GEORGIA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL ENGINEERING
ATLANTA, GA 30332

BRIEF OUTLINE OF RESEARCH FINDINGS

Research in the preceding six months has focused on efficient methods for design and implementation of two-dimensional digital filters and on algorithms for deconvolution.

Work has continued on the design of two-dimensional digital filters to approximate a given magnitude-squared frequency response function obtained by McClellan transformation of a one-dimensional magnitude-squared function. Such filters lead naturally to a very efficient and modular implementation. The design method is fast, and by performing an approximate factorization using homomorphic methods, the stability of the filter can be assured. Currently under investigation are a number of computational problems associated with the homomorphic method of spectrum factorization.

Another area of investigation has been concerned with a new method of obtaining digital filters that have response functions that are separable in a very general sense. The design method uses the two-dimensional complex cepstrum to facilitate the factorization of the frequency response of the filter into a product of factors, each of which can be viewed as a function of a single frequency variable. Such filters are particularly simple to implement, although considerably more computation is generally required.

Deconvolution is required in many situations where a desired signal is degraded or blurred by a linear filtering process. A variety of methods already exist. Major limitations of these methods are in resolving power and computational speed. Our work has focused primarily on iterative techniques that apply particularly to signals of limited extent and positive amplitude. Novel modifications to a well known class of iterative schemes have greatly improved the resolution and computational speed. The new algorithm has been tested on one-dimensional (gamma spectrum) data with very promising results. Current work is concerned with the comparison of the performance of the new algorithm to the performance of other methods. Future work will concern the application of the method to two-dimensional data.

Publications

D. B. Harris and R. M. Mersereau, "A comparison of algorithms for minimax design of two-dimensional linear phase digital filters," accepted for publication in IEEE Trans. on Acoustics, Speech, and Signal Processing, 1977.

R. M. Mersereau, "Homomorphic processing of signals," to appear as a chapter in a book, Digital Signal Processing, J. K. Aggarwal, editor, to be published by Western Periodicals, 1977.

D. B. Harris and R. M. Mersereau, "A comparison of iterative methods for optimal two-dimensional filter design," 1977 International Conference on Acoustics, Speech and Signal Processing, Hartford, CT, May 1977.

E. W. Kamen and R. M. Mersereau, "Exact and approximate decomposability of two-dimensional transfer functions," paper to be given to 20th Midwest Symposium on Circuits and Systems, Lubbock, Texas, August 1977.

E-21-683

FINAL REPORT

Contract No.: DAAG29-76-G-0226

Title: "Two-Dimensional Digital Signal Processing"

Principal Investigator: R. M. Mersereau and R. W. Schafer

During the past eighteen months research has proceeded on several research problems related to the development of two dimensional signal processing algorithms, leading to several publishable results. The specific problem areas in which results were obtained include: the design of equiripple two-dimensional FIR digital filters, two-dimensional homomorphic systems (which involved the publication of a tutorial paper), the design of decomposable recursive 2-D digital filters, the development of an efficient stability test and stabilization procedure for two-dimensional transfer functions, the development of algorithms for the deconvolution of one and two-dimensional waveforms, and the development of efficient algorithms for processing two-dimensional waveforms sampled on a hexagonal raster.