LEVEL II

Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Final Report
covering the period

January 15, 1975 - June 30, 1981

Form Approved Budget Bureau No. 22R0293

Sponsored by
Advanced Research Projects Agency
ARPA Order No. 1997

ARPA Order Number:
1997 Amend. 3, 1/22/75

Program Code Number:
80230

Contractor:
Massachusetts Institute
of Technology

Contract Number:
N00014-75-C-0951 NR-049-328

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Effective Date of Contract:
January 15, 1975

Contract Expiration Date:
June 30, 1981

Amount of Contract:
$674,139.00

Short Title of Work:
Digital Signal Processing

INTRODUCTION

This report represents the final report for the research carried out under the ARPA-ONR Contract Number N00014-75-C-0951-NR 049-328. During the course of this contract, there have been several major task areas:

1. The development of homomorphic signal processing techniques and their application to the development of a homomorphic vocoder and other signal processing applications.

2. The development and implementation of techniques for enhancement and bandwidth compression of degraded speech.

3. The development and evaluation of techniques for processing of multidimensional signals and the application of these techniques to image processing, and the processing of other multidimensional data sets.

4. The development of techniques and the implementation and evaluation of systems for speed transformations of speech.

In addition, in the course of this contract, there have been a number of other studies carried out relating to the development of signal processing techniques, as well as their implementation and application to particular problems of interest.

Throughout the course of this contract, we have reported the details of our various research efforts in the form of journal

articles and in some cases technical reports. At the end of this final report is a complete listing of the technical reports and journal articles reporting work carried out under the contract. A number of the papers supported under this contract and listed in the bibliography received major IEEE awards. In the following sections, we give a brief overview of the work carried out under the various categories indicated above.

HOMOMORPHIC SIGNAL PROCESSING

A major focus of the work under this contract has been the development of homomorphic signal processing techniques directed principally at the development of a low-cost homomorphic vocoder. As part of this work, a number of basic new algorithms were developed for homomorphic signal processing including the development of a new phase unwrapping algorithm and the development of techniques for homomorphic processing using both the conventional and sliding chirp z-transform. Also out of this study emerged a synthesis of the techniques of homomorphic filtering and linear prediction analysis. This new modified technique has been labeled as homomorphic prediction.

Much of the emphasis on the application of homomorphic techniques to speech compression has centered around the incorporation of phase. To accomplish this, a set of detailed techniques for phase estimation with particular application to speech analysis-synthesis was explored and a number of iterative techniques were developed to accomplish the phase estimation. The importance of phase in relation to speech processing, as well as the processing of other signals, was a central theme throughout this work. In addition to the development of a system for the incorporation of phase, a more general theory relating to the importance of phase in both speech and pictures was developed. This basic and fundamental work was reported in an invited IEEE paper published in May 1981.

Another modified homomorphic technique which was developed and explored in considerable detail is referred to as spectral root homomorphic deconvolution. In addition to the development of the theory, the spectral root homomorphic vocoder was implemented and evaluated.

In addition to its application to speech processing, work was carried out to explore and develop the application of homomorphic filtering in the context of seismic data processing.

SPEECH ENHANCEMENT AND BANDWIDTH COMPRESSION

A second major project during the course of this contract was the development, implementation and evaluation of techniques for enhancement and bandwidth compression of degraded speech. The principal accomplishments on this project were reported in detail in an invited review paper published in the IEEE Proceedings in December 1979. The system which was developed and implemented centered around the all-pole modeling of speech taking into account the noisy observations. In addition to the implemented system being better in performance than other previous systems, a considerable body of important and useful theory relating to the modeling of signals which have been degraded by noise was developed.

MULTIDIMENSIONAL SIGNAL PROCESSING

Our work on multidimensional signal processing had a very strong component relating to the development of the theory for multidimensional filtering and spectral analysis. A number of new multidimensional filter design techniques were developed and are now widely used throughout the community. Much of our early work in this area was published in an invited paper in the IEEE Proceedings on two-dimensional digital filtering. Important results were also obtained under this project on multidimensional spectral analysis. A basic new algorithm for two-dimensional maximum entropy power spectrum estimation was developed which resolves many of the algorithm problems previously encountered in relation to multidimensional power spectrum analysis. A new class of algorithms was also developed for the numerical evaluation of the hankel transform which corresponds to the two-dimensional Fourier transform of a circularly symmetric function. This latte algorithm was motivated in part by a problem relating to the measurment of the plane wave reflection coefficient of the ocean bottom and is now generally considered to be one of the most efficient algorithms for the computation of the hankel transform.

The theory that has been developed under this project for multidimensional signal processing has been applied in a number of areas. One, as indicated above, is in problems relating to

ocean acoustics. Also, much of the work has been implemented in relation to problems of image enhancement and restoration including the restoration of speckle images.

SPEED TRANSFORMATIONS OF SPEECH

During this contract, we developed, implemented, and investigated in detail techniques for speed transformations of speech, in particular, techniques for speeding up and slowing down speech while retaining very high quality. In addition to a successful implementation which resulted in a system of considerably higher quality than had ever previously been achieved, a basic new theory resulted on the short time Fourier analysis of speech and the use of this theory in the implementation of the digital phase vocoder.

GENERAL SIGNAL PROCESSING

In part as an outgrowth of the projects described above a number of other important studies were carried out under this contract. A theory was developed for the analysis of linear digital networks which was published in an IEEE invited paper. Work on computer architectures for signal processing, also published as an IEEE Proceedings invited paper, was carried out. More recently work under this contract, motivated in large part by our previous work on the importance of incorporating phase

information in vocoders, was carried out on the importance of phase in signals. Out of this study has emerged a rich and potentially very significant theory on signal reconstruction from either phase or magnitude information in the time domain or frequency domain.

PUBLICATIONS 1975 - 1981
under Contract N00014-75-C-0951-NR 049-328

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