Several research topics related to the delta-operator have been studied. Firstly, we are completing our research on the delta-operator based efficient stability tests by tying all loose ends and presenting the results in various coherent ways. Secondly, a delta-operator based least squares lattice algorithm has been developed. The new algorithm is computationally efficient, and has better numerical properties than the existing ones. Thirdly, more results have been obtained in the least squares method using the "generalized delta operator". In one of these new results, a computationally efficient algorithm using the delta operator has been developed to estimate continuous-time autoregressive process parameters from discrete-time data. Other topics such as blind equalization have also been studied and further results obtained.

**Subject Terms:**
- delta operator
- stability tests
- least squares lattice
- continuous-time AR processes
- blind equalization
This period is the second annum under this new grant. Our efforts are focused on the following activities:

1. Continue to study and disseminate the delta-operator based stability test algorithms, due to the importance of this subject. We have revised and published some previously submitted journal papers (B2), and have published a conference paper (I2). We are completing this important subject in many details, and are preparing to write a book on it. The PI also organized an invited session on the delta operator in systems, control, and signal processing for the coming IEEE Conference on Decision and Control to be held in San Diego in December 1997.

2. Our study shows that the delta operator based signal processing algorithms seem to give comparable numerical behavior as the QRD based algorithms, whereas their combination does not seem to give any further improvement in numerical behavior. We are currently studying this phenomenon, in trying to understand why this is the case. Meanwhile, we have improved our previous results on delta-operator Levinson and Schur algorithms to have achieved yet much better results than before (see publication H2). Recently we have also developed a delta least squares lattice algorithm. This algorithm has very high computational efficiency (at the order of O(N) where N is the order of the lattice filter) and better numerical accuracy that the traditional least squares lattice algorithm under fast sampling. We have submitted a conference paper to ICASSP '98, and will be submitting a journal paper shortly. During this period we also published a conference paper on our results about the modified normalized lattice and its limit as the sampling frequency approaches infinity (I3). This result had been reported last year.

3. The cooperative research on the "generalized delta operator" with the Swedish researchers led by Prof. Söderström turns out to be quite "profitable". We concentrate our study on identification of continuous-time ARX model parameters using discrete-time data and either the delta operator or the generalized delta operator. Not only have we published our first result using the least squares approach in the journal form (B3), we also have obtained further interesting results in terms of bias compensation and ways of coping with additive noise. Some of the new results have been presented recently in a conference (I1). We have also submitted a conference paper to ICASSP'98, and submitted a journal paper as well (A3). The results with additive noise will also be submitted and published in the near future.

4. Blind Equalization. This work is a continuation of the last year's work which was jointly supported by the AASERT program under Grant N00014-93-1-1032 (expired). We have constructed a family of new cost functions which work at least as well as the well known constant modulus algorithm (CMA), also known as the Godard-2 algorithm, but may even potentially be better than the CMA. We have submitted two journal papers (A1 and A2) and presented one more conference paper (I4). We have also filed a provisional patent application on this technique (F1). Recently we have developed a stochastic Newton-like algorithm for blind equalization. The new algorithm applies to many cost functions including the CMA and our own, and converges much faster than the existing algorithms. The computational complexity is O(N^2). We have submitted a conference paper to ICASSP'98. Currently we are working on its fast
implementation (QRD-LSL-like) which will have a computational complexity of only $O(N)$, and will be filing another patent application on these results.

5. Continue to work on other aspects which were initiated before. One of them is the robustness issue in our previous work on linear time-varying system modelling using wavelets. We have shown that our previous approach, which was reported previously, is robust to narrow band noise or impulsive noise. We presented an invited paper at a recent conference (H1) and have also submitted a journal paper on this subject (A4). We have also overseen the publication processes to completion for the papers (B1) and (B4).
OFFICE OF NAVAL RESEARCH
PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT
for
1 October 1996 through 30 Sept. 1997

Contract/Grant Number: N00014-96-1-0241
Contract/Grant Title: High Speed, Numerically Superior Signal Processing Algorithms Using QRD and Delta Operator
Principal Investigator: Dr. H. (Howard) Fan
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a. Number of Papers Submitted to Refereed Journals but not yet published: 4
b. Number of Papers Published in Refereed Journals: 4
c. Number of Books or Chapters Submitted but not yet Published: 0
d. Number of Books or Chapters Published: 1
e. Number of Printed Technical Reports & Non-Refereed Papers: 0
f. Number of Patents Filed: 1
g. Number of Patents Granted: 0
h. Number of Invited Presentations at Workshops or Prof. Society Meetings: 2
i. Number of Presentations at Workshops or Prof. Society Meetings: 4
j. Honors/Awards/Prizes for Contract/Grant Employees: 0
k. Total number of Graduate Students and Post-Docs Supported at least 25%, on this contract/grant:
   Grad Students 3       and Post Docs 0

   How many of each are females or minorities? (These
6 numbers are for ONR's EEO/Minority Reports:
minorities include Blacks, Aleuts Aminidians,
etc. and those of Hispanic or Asian extraction/nationality. These Asians are singled out to
facilitate meeting the varying report semantics re "under-represented").

   |   Grad Student Female  |
   |   Grad Student Minority |
   |   Grad Student Asian e/n | 3 |
   |   Post-Doc Female       |
   |   Post-Doc Minority     |
   |   Post-Doc Asian e/n    |
A. PAPERS SUBMITTED TO REFEREED JOURNALS


B. PAPERS PUBLISHED IN REFEREED JOURNALS


D. BOOKS OR CHAPTERS PUBLISHED

The following paper


has been selected to be included in the following edited book:


F. PATENTS FILED

H. INVITED PRESENTATIONS AT PROFESSIONAL SOCIETY MEETINGS


I. PRESENTATIONS AT PROFESSIONAL SOCIETY MEETINGS


K. GRADUATE STUDENTS SUPPORTED UNDER THE CRP FOR THIS PERIOD

1. P. De, Ph.D. candidate

2. G. Yan, Ph.D. candidate (partially supported)

3. X. Li, Ph.D. candidate (partially supported)