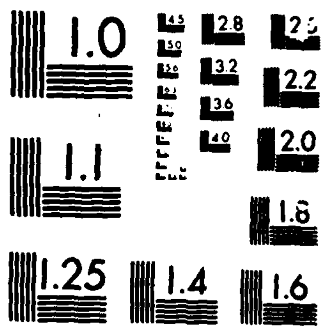

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The investigator has been working on parallel algorithms for various aspects of the linear control problem. Fast sequential and parallel algorithms have been developed for (i) determining relative primeness and the number of common eigenvalues between two given matrices and (ii) finding inertia and stability of a matrix.

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RESEARCH PROGRESS AND FORECAST REPORT

On

"Sequential and Parallel Matrix Computations"

By

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AFOSR-82-0210

Presented to Air Force Office of Scientific Research

The design and analysis of Linear Control Systems governed by the systems of differential equations:

$$\dot{\chi}(t)=A\chi(t)+Bu(t)$$

and

$$\chi_{k+1}(t)=A\chi_k(t)+Bu_k(t)$$

Where A and B are constant matrices of appropriate dimensions and χ and u are time dependent vectors, give rise to a variety of interesting linear algebra problems such as

1) Stability and Inertia problems

2) Controllability problem

3) Pole assignment problems

4) Matrix equations problems

5) Cauchy-index problems of rational functions etc.

The major objectives of the project are to develop fast sequential and parallel algorithms for these problems and to study their parallel arithmetic complexities.

Some remarkable progress has been made in the last year. In my "INTERIM REPORT" last October, I listed several of the accomplishments. Since then, the following additional accomplishments have been made.

(A) Fast sequential and parallel algorithms have been developed for (i) determining relative primeness and the number of common eigenvalues between two given matrices (ii) finding inertia and stability of a matrix. Sequentially, these algorithms are more efficient than the existing ones and in parallel, they can be implemented in almost linear time steps using almost $0(n^2)$ processors. An important feature of these algorithms is that they comprise only the basic linear algebra operations for which there do already exist effective parallel algorithms. Thus, these algorithms seem to be suitable for implementations on the existing and future parallel architectures. In fact, these are presently being implemented on the DENELCOR HEP at Argonne National Laboratory. These results were presented by the principal investigator in an INVITED TALK at the AMS Research Conference on "Linear Algebra and its Role in Systems Theory", Maine, July 1984. The paper has been accepted for publication in a special issue of "CONTEMPORARY MATHEMATICS" on "Linear Algebra and Systems Theory" to be published by the AMS.

(B) In the paper "Parallel Arithmetic Complexities of Some Linear Algebra Problems in Control Theory" we reported, among other things, of the parallel algorithms for (i) controllability problem of the pair (A,B); where A is a companion matrix but B is full (ii) stability and inertia problems for polynomials and (iii) Cauchy index problem of a rational function. These algorithms required $0(n\log_2 n)$ parallel steps using $0(n^2)$ processors. However, we have just developed new and in some cases modified algorithms for these problems which have sequential complexity of $0(n^2)$ and can be implemented in parallel in $0(n)$ steps with $0(n)$ processors only. Recently developed techniques of fast matrix computations for Toeplitz and Hankel matrices are used in these algorithms. The savings in time and especially in processors ~~is~~ are significant. The results are presently being written up.

(C) The parallel arithmetic complexity of QR factorization of a matrix A has been shown to be upper bunded by $(0\log_2^2 n)$ steps. As an application of this result, a parallel algorithm requiring only $0(\log_2 n)$ steps and $0(n)$ processors for computing the eigenvalues of a symmetric tridiagonal matrix has been developed. The paper based on these results has been accepted for publication in International Journal of Computers.

(D) A new result on the existence, uniqueness and nonsingularity of solutions of a special type of sylvester equation has been obtained. As applications of these results direct methods have been developed for constructing symmetrizors, computing matrices, computing the characteristic polynomial of a matrix and finding the numbers of common eigenvalues between two matrices. These results are reported in the paper "The Matrix Equation LA-BL=R and its Applications" The paper is presently submitted for publication. K. Datta will present a talk based on this paper in the upcoming SIAM Conference on Applied Linear Algebra, Raleigh, N.C., April 29 - May 3, 1985.

Some of the results reported in this report were presented by the principal investigator in an INVITED KEY NOTE ADDRESS at the International Conference on Linear Algebra and its applications. Coimbra, Portugal, October, 1984. Other results will be presented by P.I. in an INVITED SESSION on "Linear Algebra and Systems Theory" at the International Conference on Mathematical Theory of Networks and Systems, Stockholm, Sweden, June 10-June 14, 1985. This invited Session has been organized by P.I. on a special invitation by the organizing committee.

Future Plans: In the near future, besides continuing our current research, we plan to develop fast sequential and parallel algorithms for large scale control problems. As is well-known that the reduction of an arbitrary matrix into a Hessenberg matrix using Householder's or Given's method is not effective for large and sparse matrices, because sparsity may be lost during the process. On the other hand, iterative Lanczos and Arnoldi algorithms have been found to be very effective for these matrices at least in symmetric cases for solving linear systems and finding eigenvalues. We plan to use these as well as other iterative algorithms for solving large scale control problems. We have already started work and the following progress has been made jointly with A. Sameh of University of Illinois at Urbana- Champaign.

(i) It has been observed that the relationship between the QR factorization of a matrix A and Lanczos algorithm for symmetric eigenvalue problem can be exploited to solve the controllability problem for the pair (A,b); where A is large, sparse and symmetric and b is a column vector.

(ii) The single-input pole assignment for a large, sparse symmetric tridiagonal matrix has been solved.

The area Large Scale Computing for Linear Control Problems is virtually untouched. We plan to take a "Lead" in this area. Work just started. A lot remains to be done.

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