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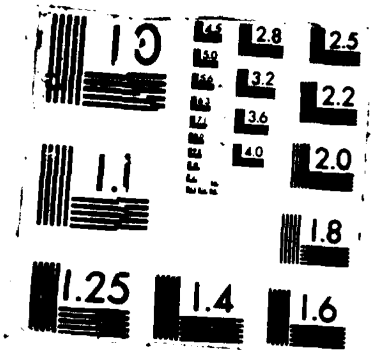
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The goal of this research is to develop computational algorithms for identification and control, especially with application to aeroelastic and viscoelastic systems. The research has emphasized development of Chandresekhar algorithms for optimal control of distributed systems and state models and computational algorithms for aeroelastic control systems. During this period, the investigators developed fast algorithms for the general linear quadratic optimal control problems for functional differential equations using Chandresekhar factorization techniques. The resulting algorithms show improved rates of convergence over Ricatti techniques and for certain large problems is the only algorithms which was shown to converge in practice. Nine publications were produced during this period under this grant, including "Factorization and Reduction Methods for Optimal Control of Hereditary Systems" and "Modeling and Approximation for a Ciscoelastic Control Problem".

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MODELING AND COMPUTATIONAL ALGORITHMS FOR PARAMETER ESTIMATION AND OPTIMAL CONTROL OF AEROELASTIC SYSTEMS AND LARGE FLEXIBLE STRUCTURES

AFOSR GRANT AFOSR - 85 - 0287

for

30 September 1985 - 30 September 1986

by

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1 November 1986

PROGRESS REPORT

The general goal of this research is the development of computational algorithms for identification and control of distributed parameter systems that model various elastic, aeroelastic and viscoelastic systems. The initial efforts under this grant has been concerned with three aspects of these problems:

1. The application of Chandrasekhar type algorithms to optimal control problems for distributed parameter systems.

2. The development of well-posed state space models and computational schemes for aeroelastic control systems.

3. The development of a state space model and a convergent approximation scheme for a viscoelastic material.

During this period we concentrated on the development of fast algorithms for the general linear quadratic optimal control problem for distributed parameter systems governed by retarded functional differential equations. This algorithm combines a Chandrasekhar factorization technique with special "F-reduction" schemes to produce a fast computational scheme for computing feedback gains. Convergence of the algorithm has been established and the algorithm has been tested on a number of hereditary control problems (including an aeroelastic control problem). The results are extremely nice in that when the algorithm is compared to standard Riccati based methods, the factorization method always showed improved rates of convergence. **In many cases actual CPU time was reduced by an order of magnitude.** Moreover, in large problems (such as aeroelastic and viscoelastic control problems) the hybrid factorization-reduction scheme was the only algorithm that converged! These results are reported in [1] and [2].

In order to develop computational methods for identification and control of aeroelastic systems, we have devoted considerable effort to the analysis of well-posed models for the typical section. For two dimensional, subsonic and incompressible flow the basic governing equation is a neutral functional differential equation with non-atomic difference operator. We have established the well-posedness of this model and constructed a convergent numerical scheme. Although this scheme appears suitable for simulation and identification, it is not very useful as a computational tool for control design. The well-posedness results are presented in [3], [5] and [6] and the numerical scheme is given in [9]. More analysis of these types of models is needed before we can develop a real understanding of the problems associated with constructing practical computational algorithms that are suitable for control design.

We have investigated a number of state space models for viscoelastic structures of Boltzmann type and we have established the convergence of a finite element/averaging numerical scheme for certain simple systems of this type. This problem has lead to two new discoveries that are somewhat surprising. First it was learned (see [7] and [8]) that a combined finite element/averaging scheme does not produce an unconditionally convergent scheme. If N denotes the number of "finite elements" in the spatial approximation and M denotes the number of approximations of the hereditary system, then the finite element/averaging scheme is stable only if

$$M > N^p$$

for some p > 1. This result implies that this scheme may be slow to converge and early numerical test indicate that this is the case. Better algorithms need to be developed. We are looking into this question. We also discovered that Boltzmann type models can be used to study a wide range of damping models in structures. This observation could lead to a parameterization of damping models that would be suitable for parameter identification algorithms that would identify the "type" of damping in a given structure. We hope to look into this problem in the near future.

There is little known about the effect of approximation schemes on the system theoretic properties of the distributed parameter system being approximated. For example, what types of approximation schemes lead to controllable finite dimensional models if it is given that the infinite dimensional system is exactly controllable (or approximately controllable, etc.)? We have started to look at this type of question and initial results on such questions appear in [4].

DURING THIS PERIOD THE FOLLOWING PAPERS WERE PREPARED

1. J.A. Burns and R.K. Powers, Factorization and Reduction Methods for Optimal Control of Hereditary Systems, **Mathematica Applicada E Computational**, 1987, to appear.

2. J.A. Burns, E.M. Cliff and R.K. Powers, Modeling and Control of an Aeroelastic System, **Fourth IFAC Symposium on Control of Distributed Parameter Systems**, UCLA, June 1986, to appear.

3. J.A. Burns, T.L. Herdman and J. Turi, Well-posedness of Functional Differential Equations with Nonatomic D- Operators, **Sixth Int'l. Conference on Nonlinear Analysis**, V. Lakshmikantham, ed., Academic Press, New York, 1985, 71-77.

4. J.A. Burns, E.M. Cliff and R.K. Powers, Computational Methods for Control of Distributed Parameter Systems, **24th IEEE Conference on Decision and Control**, Ft. Lauderdale, Fl, December, 1985, 1994-1998.

5. J.A. Burns, T.L. Herdman and J. Turi, Nonatomic Neutral Functional Differential Equations, **Nonlinear Analysis and Applications**, to appear.

6. J.A. Burns, E.M. Cliff, T.L. Herdman and J. Turi, On Integral Transforms Appearing in the Derivation of the Equations of an Aeroelastic System, **Nonlinear Analysis and Applications**, to appear.

7. J.A. Burns and R. Fabiano, Modeling and Approximation for a Viscoelastic Control Problem, **Third Int'l. Conference on Distributed Parameter Control**, Graz, Austria, July, 1986, to appear.

8. R. Fabiano, Approximations of Integro-partial Differential Equations of Hyperbolic Type, Ph.D. Thesis, Department of Mathematics, Virginia Polytechnic Institute and State University, Blacksburg, VA, June, 1986.

9. J. Turi, Well-posedness and Approximation Schemes for Neutral Functional Differential Equations, Ph.D. Thesis, Department of Mathematics, Virginia Polytechnic Institute and State University, Blacksburg, VA, June, 1986.

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