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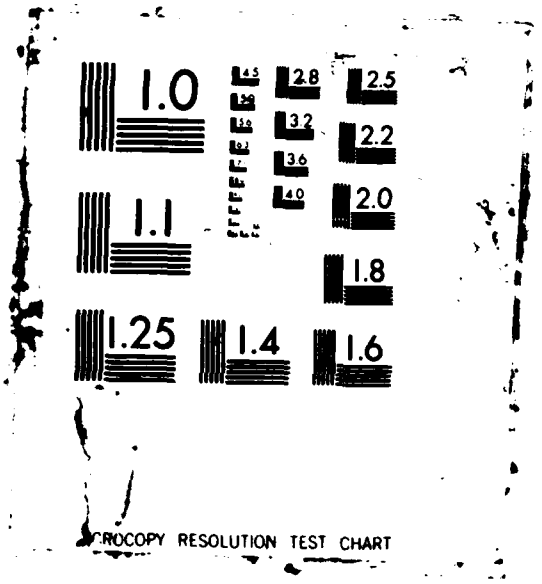
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The research covered by this report was aimed at laying the groundwork for a long term project on the integrated, optimization-based design of large, flexible structures and their control systems. To this end, research was carried out in four areas: (i) modeling of the dynamic behavior of simple flexible structures; (ii) the development of a theory of nondifferentiable optimization algorithms for the solution problems with max type inequality constraints; (iii) the exploration of the use of optimization in control system

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AN INTEGRATED, OPTIMIZATION-BASED APPROACH TO THE DESIGN AND CONTROL OF LARGE SPACE STRUCTURES

Final Technical Report
AFOSR Grant 83-0361
(October 1, 1983 - September 30, 1986)

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The research covered by this report was aimed at laying the groundwork for a long term project on the integrated, optimization-based design of large, flexible structures and their control systems. To this end, research was carried out in four areas: (i) modeling of the dynamic behavior of simple flexible structures; (ii) the development of a theory of nondifferentiable optimization algorithms for the solution of problems with max function type inequality constraints; (iii) the exploration of the use of optimization in optimization-based design of large, flexible structures and their control systems; and finally, (iv) interactive software for optimization-based control system design.

(i) As a first step in this project, it was necessary to construct some simple models which captured the essence of large, flexible structure behavior and corresponding computational difficulty. Our work on modeling the dynamic behavior of simple flexible structures concentrated on the large motion structural simulation of beam systems. In this work, consistent linearizations were introduced to develop the necessary algorithms for a finite element solution. The consistent linearizations ensure that a correct linear model is deduced about any operational state and thus may be used as the basis for closed loop designs as well. The results of this research were written up in references [16-22]. and have either been published in journals or have been submitted for publication.

(ii) Since 1984, we have been working on a constructive theory of nondifferentiable optimization algorithms. The purpose of this theory is to elucidate the principles of nondifferentiable optimization algorithm construction. A first version of this theory

appeared in [3], it was further refined in [4] and it will appear in final form in SIAM Review in February 1987. The SIAM Review is probably the only publication where one can publish a paper dealing with a new and complex theory in an expository fashion. Our manuscript is well over 100 pages long and, hopefully, sufficiently self contained to open up our algorithms and algorithm construction tools to a wide audience. The most important aspects of our work are (a) the discovery of a mechanism for generating continuous search direction functions which lead to extremely well behaved optimization algorithms, and (b) the discovery that the generation of nondifferentiable optimization algorithms is "elastic" in the sense that one can generate endless families of nondifferentiable optimization algorithms. There are two important consequences to this elasticity, the first is that it has enabled us to construct new, quadratically convergent algorithms for semi-infinite optimization (manuscript in preparation) and the second is that it opened up new avenues for scaling algorithms so as to enhance their behavior. The exploration of the latter has become the topic of a doctoral dissertation.

(iii) Our work on optimization-based control system design was reported in [1] and [4] to [15]. In [1 , 12 , 14] we presented our work on worst case design in the presence of structured and unstructured uncertainty. Our major contribution in this area is a computational complexity reduction scheme. In [6] and [7] we showed that it is possible to define an uncertainty identification scheme which can be used to produce information for redesigning the control system under worst case assumptions. We showed that this new approach to adapative control results in a stable system whose perfor-

mance improves with time, as the system uncertainty is reduced. In [15] and a follow up paper, in preparation, we show that our semi-infinite optimization algorithms can be used for solving H_∞ constrained optimization problems, with both *frequency domain and time domain* constraints. Thus our algorithms considerably advance the possibilities of design using H_∞ concepts, as well as control system design with respect to other norms. We are currently exploring techniques for extending these results for the design of *finite dimensional* stabilizing controllers for large, flexible structures. Our research on optimal control algorithms, which can be used for solving optimal control problems with either ODE or PDE type dynamics, control and state space constraints, was presented in [11]. Finally, our work on control system design formulation as a semi-infinite optimization problem and on simulation techniques for optimization-based control system design were presented in [4 , 5 , 8 , 13]. Finally, [9 , 10] present some preliminary results on algorithms dealing with collision avoidance problems.

(iv) Our interactive, optimization-based computer-aided multivariable control system design package, DELIGHT.MIMO, has recently been completed and is being placed in alpha sites for testing and evaluation. Hopefully, it will simplify considerably the use in industry of optimization-based computer-aided control system design tools. An important aspects of this package is a very friendly graphical user interface which makes the definition of system interconnections and transcription of a design problem into an optimization problem a simple, error free task. In addition, by powerful windowing techniques, it allows the user to examine simultaneously various systems outputs as well as their variations produced by user dictated design parameter changes.

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