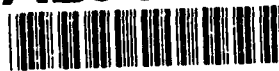


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1. AGENCY REPORT NUMBER: [blank] 2. REPORT DATE: [blank] 3. REPORT TYPE AND DATES COVERED: FINAL 01 OCT 90 to 03 SEP 91

4. TITLE AND SUBTITLE: OPTIMAL DESIGN AND CONTROL OF DISTRIBUTED PARAMETER SYSTEMS  
5. FUNDING NUMBERS: AFOSR-91-0008  
61102F 2304/A1  
6. AUTHOR(S): THOMAS I. SEIDMAN

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES): UNIVERSITY OF MARYLAND, BALITMORE COUNTY  
5401 WILKENS AVENUE  
BALTIMORE, MD 21228  
8. PERFORMING ORGANIZATION REPORT NUMBER: AFOSR-TR-92-0623

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES): AFOSR/NM  
Bldg 410  
Bolling AFB DC 20332-6448  
10. SPONSORING/MONITORING AGENCY REPORT NUMBER: AFOSR-91-0008

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AUG 27 1992  
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11. SUPPLEMENTARY NOTES: [blank]

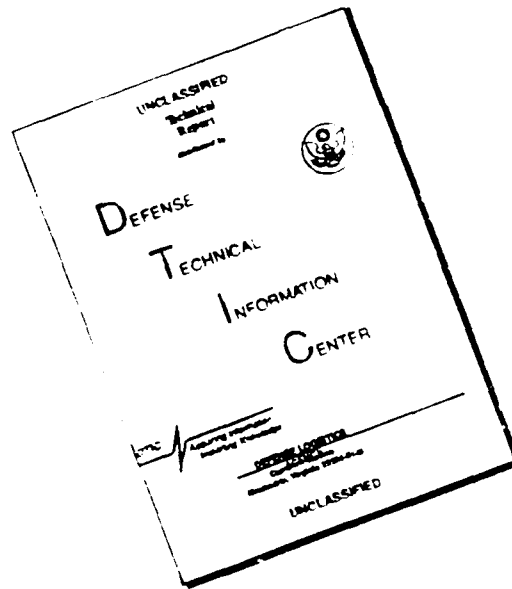
12a. DISTRIBUTION/AVAILABILITY STATEMENT: Approved for public release; Distribution unlimited  
12b. DISTRIBUTION CODE: UL

13. ABSTRACT (Maximum 200 words):  
Research has been conducted on nonlinear optimization in the areas of (i) dual based methods and decomposition; (ii) regularization and approximation techniques; (iii) nonsmooth optimization and (iv) algorithms development for large-scale optimization. The methods developed are applicable to a wide range of important applications including; optimal shape design, structural optimization, and image reconstruction.  
82 8 26 079 92-23769 388411 2pp

14. SUBJECT TERMS: [blank] 15. NUMBER OF PAGES: [blank]  
16. PRICE CODE: [blank]

17. SECURITY CLASSIFICATION OF REPORT: UNCLASSIFIED  
18. SECURITY CLASSIFICATION OF THIS PAGE: UNCLASSIFIED  
19. SECURITY CLASSIFICATION OF ABSTRACT: UNCLASSIFIED  
20. LIMITATION OF ABSTRACT: SAR

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FINAL PROGRESS REPORT: #AFOSR-91-0008

OPTIMAL DESIGN AND CONTROL OF  
DISTRIBUTED PARAMETER SYSTEMS

University of Maryland Baltimore County

Thomas I. Seidman

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Much of the work here has been computationally oriented, focusing on a variety of problems involving a varying region whose boundary is to be determined (i.e., free boundary problems and shape optimization). The computational approaches have included use of boundary tracking with remeshing, applying an auxiliary function on a fixed grid, and reformulation as a boundary element method (BEM).

Collaboration has continued with a group at Université de Paris-Sud (Orsay) on theoretical and computational approaches to a problem of tracking the evolution of a solid/liquid interface at which one has accretion or dissolution of a substance dissolved and diffusing (possibly with chemical reactions) in the liquid phase. Both fixed and adaptive mesh algorithms have been developed and are to be implemented for comparative study. Of interest are the computational technique itself, the average interfacial velocity, and the stability of the shape.

A model problem for structural optimization is being studied jointly with C. Schwab. After derivation of the variation for the relevant functional as a boundary integral, this is being computationally treated via BEM. For the simplest case (only an area constraint) the exact solution is known. The method has been implemented for this and rapidly finds the optimal shape for rather general initial shapes. Two interesting difficulties arise for which

investigation continues: (i) since the computational boundary is inevitably polyhedral, one must treat corner singularities and this has proved surprisingly tricky in practice, (ii) maintaining accuracy can be expected to require occasional remeshing and so alteration of the dimensionality of the outer optimization problem. The latter question also occurs in consideration of a coordinated approach to refinement of discretization and optimization, now under analysis.

Other activity includes work on: (i) switching systems, (ii) ill-posed problems, (iii) collaboration with S. Antman on a problem of nonlinear viscoelasticity (longitudinal motions of a rod), and initiation of collaboration with S. Lenhart on bioremediation. Activity in (i) includes a Ph.D. degree for W. Szczechla, extension of results by Filippov, Utkin, etc., on sliding modes arising in hybrid (variable mode) systems, and collaboration with M. A. Krasnosel'skii on existence of periodic solutions of forced systems. Work in (iii) has now led to a proof that a certain inequality constraint on the constitutive relation implies the impossibility of infinite compression. Finally, work in (iv) has resulted in an interesting formulation of a bioremediation problem involving ODEs with discontinuous right hand side, as in (i); the optimal control problem is now under consideration, as is the extension to a Distributed Parameter problem involving flow of ground water and a free boundary problem.

## Marc Teboulle

Within the general framework of the proposal, work on nonlinear optimization has been primarily in the areas of: (i) dual-based methods and decomposition, (ii) regularization and approximation techniques, (iii) nonsmooth optimization, and (iv) algorithm development for large-scale optimization. These methods are applicable to a wide range of important applications including, e.g., optimal shape design, structural optimization, and image reconstruction. Since the high dimensionality of these problems poses severe computational challenges, work has focused on dual-based and augmented Lagrangian methods taking advantage of available special structure to permit natural decompositions for which parallel iterative methods can be utilized effectively.

In particular, this methodology has been applied to problems of structural optimization and image reconstruction. Initial analysis and supporting technical material are described in a sequence of papers, partly in collaboration with a doctoral student G. Chen and with A. Iusem. Related work on approximation of a class of optimization problems and application of optimization methods to problems of robust stabilization has been in collaboration with J. Kogan and with I. Vajda.

Papers by Teboulle and by Chen and Teboulle introduce the basic theory and convergence analysis for constructing a general new class of augmented Lagrangians. The approach is giving rise to new multiplier methods which appear to have many attractive characteristic properties and which are useful for decomposition; in particular, these are as differentiable as the data permits, opening the possibility of applying second-order methods after decomposition to smaller problems.

A byproduct is a way to generate highly parallelizable methods for solution of discrete-time deterministic control problems. Some resemblance to recent work of Rockafellar suggests the possibility of extension to linear-quadratic problems arising in multistage stochastic programs, etc. Initial results will appear in a paper with Chen. This approach should be particularly useful for structural optimization problems which, as typically occurs, have a large but tractable inner problem and a smaller but difficult (nonsmooth) outer problem.

Another application is to an optimization formulation of image reconstruction. In a paper by Teboulle, a convex regularization process for linear inverse problems is treated via duality methods. An iterative method for a specific image reconstruction from noisy projections was studied with Iusem, using a regularization of the objective functional, enforcing smoothness to improve the quality of the images.