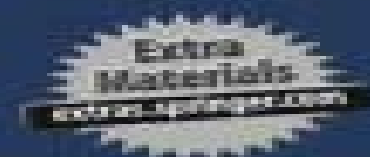


*Modeling and Simulation in
Science, Engineering and Technology*

Numerical Methods in Sensitivity Analysis and Shape Optimization

*Emmanuel Laporte
Patrick Le Tallec*



B I R K H Ä U S E R

Numerical Methods In Sensitivity Analysis And Shape Optimization

Max D. Gunzburger



Numerical Methods In Sensitivity Analysis And Shape Optimization:

Numerical Methods in Sensitivity Analysis and Shape Optimization Emmanuel Laporte, Patrick Le Tallec, 2012-12-06 Sensitivity analysis and optimal shape design are key issues in engineering that have been affected by advances in numerical tools currently available This book and its supplementary online files presents basic optimization techniques that can be used to compute the sensitivity of a given design to local change or to improve its performance by local optimization of these data The relevance and scope of these techniques have improved dramatically in recent years because of progress in discretization strategies optimization algorithms automatic differentiation software availability and the power of personal computers Numerical Methods in Sensitivity Analysis and Shape Optimization will be of interest to graduate students involved in mathematical modeling and simulation as well as engineers and researchers in applied mathematics looking for an up to date introduction to optimization techniques sensitivity analysis and optimal design

Introduction to Shape Optimization Jan Sokolowski, Jean-Paul Zolesio, 2012-12-06 This book is motivated largely by a desire to solve shape optimization problems that arise in applications particularly in structural mechanics and in the optimal control of distributed parameter systems Many such problems can be formulated as the minimization of functionals defined over a class of admissible domains Shape optimization is quite indispensable in the design and construction of industrial structures For example aircraft and spacecraft have to satisfy at the same time very strict criteria on mechanical performance while weighing as little as possible The shape optimization problem for such a structure consists in finding a geometry of the structure which minimizes a given functional e g such as the weight of the structure and yet simultaneously satisfies specific constraints like thickness strain energy or displacement bounds The geometry of the structure can be considered as a given domain in the three dimensional Euclidean space The domain is an open bounded set whose topology is given e g it may be simply or doubly connected The boundary is smooth or piecewise smooth so boundary value problems that are defined in the domain and associated with the classical partial differential equations of mathematical physics are well posed In general the cost functional takes the form of an integral over the domain or its boundary where the integrand depends smoothly on the solution of a boundary value problem

Shape Design Sensitivity Analysis and Optimization Using the Boundary Element Method Zhiye Zhao, 2012-12-06 This book investigates the various aspects of shape optimization of two dimensional continuum structures including shape design sensitivity analysis structural analysis using the boundary element method BEM and shape optimization implementation The book begins by reviewing the developments of shape optimization followed by the presentation of the mathematical programming methods for solving optimization problems The basic theory of the BEM is presented which will be employed later on as the numerical tool to provide the structural responses and the shape design sensitivities The key issue of shape optimization the shape design sensitivity analysis is fully investigated A general formulation of stress sensitivity using the continuum approach is presented The difficulty of

the modelling of the adjoint problem is studied and two approaches are presented for the modelling of the adjoint problem. The first approach uses distributed loads to smooth the concentrated adjoint loads and the second approach employs the singularity subtraction method to remove the singular boundary displacements and tractions from the BEM equation. A novel finite difference based approach to shape design sensitivity is presented which overcomes the two drawbacks of the conventional finite difference method. This approach has the advantage of being simple in concept and easier implementation. A shape optimization program for two dimensional continuum structures is developed including structural analysis using the BEM shape design sensitivity analysis mathematical programming and the design boundary modelling.

Numerical Methods for Optimal Control Problems Maurizio Falcone, Roberto Ferretti, Lars Grüne, William M. McEneaney, 2019-01-26

This work presents recent mathematical methods in the area of optimal control with a particular emphasis on the computational aspects and applications. Optimal control theory concerns the determination of control strategies for complex dynamical systems in order to optimize some measure of their performance. Started in the 60s under the pressure of the space race between the US and the former USSR the field now has a far wider scope and embraces a variety of areas ranging from process control to traffic flow optimization, renewable resources exploitation and management of financial markets. These emerging applications require more and more efficient numerical methods for their solution, a very difficult task due to the huge number of variables. The chapters of this volume give an up to date presentation of several recent methods in this area including fast dynamic programming algorithms, model predictive control and max plus techniques. This book is addressed to researchers, graduate students and applied scientists working in the area of control problems, differential games and their applications.

Shape Optimization Problems Hideyuki Azegami, 2020-09-30. This book provides theories on non parametric shape optimization problems systematically keeping in mind readers with an engineering background. Non parametric shape optimization problems are defined as problems of finding the shapes of domains in which boundary value problems of partial differential equations are defined. In these problems optimum shapes are obtained from an arbitrary form without any geometrical parameters previously assigned. In particular problems in which the optimum shape is sought by making a hole in domain are called topology optimization problems. Moreover a problem in which the optimum shape is obtained based on domain variation is referred to as a shape optimization problem of domain variation type or a shape optimization problem in a limited sense. Software has been developed to solve these problems and it is being used to seek practical optimum shapes. However there are no books explaining such theories beginning with their foundations. The structure of the book is shown in the Preface. The theorems are built up using mathematical results. Therefore a mathematical style is introduced consisting of definitions and theorems to summarize the key points. This method of expression is advanced as provable facts are clearly shown. If something to be investigated is contained in the framework of mathematics setting up a theory using theorems prepared by great mathematicians is thought to be an extremely effective approach. However

mathematics attempts to heighten the level of abstraction in order to understand many things in a unified fashion This characteristic may baffle readers with an engineering background Hence in this book an attempt has been made to provide explanations in engineering terms with examples from mechanics after accurately denoting the provable facts using definitions and theorems

Sensitivity analysis and shape optimization of geometrically non-linear structures, 2000 Este trabalho prop e uma metodologia para a otimizao de forma de estruturas geometricamente n o lineares O objetivo desta metodologia evitar os problemas de instabilidade apresentados por estruturas otimizadas de acordo com a formulao cl ssica Ela foi implementada para problemas bidimensionais e os resultados obtidos na otimizao de diferentes estruturas demonstraram o seu sucesso Utilizando-se conceitos de modelagem geomtrica a forma da estrutura definida atravs das curvas de seu contorno Assim a representao paramtrica de curvas e definida em funo de um conjunto de pontos de interpola o pontos chave s o discutidas detalhadamente A nfase dada interpola o atravs de B splines devido a sua grande flexibilidade O problema de otimizao definido com base no modelo geomtrico e as variaveis de projeto s o as coordenadas dos pontos chave A simetria da estrutura garantida atravs da ligao de variaveis A estrutura analisada atravs de elementos isoparametricos planos Assim antes de realizar a anlise necessrio discretizar a estrutura em um conjunto de elementos finitos Para realizar esta tarefa foram implementados diferentes algoritmos de gerao de malhas tanto estruturadas quanto n o estruturadas O m todo de Newton Raphson utilizado para determinar a configurao de equilbrio e diferentes m todos podem ser aplicados para determinar os pontos crticos Devido aos problemas de convergncia apresentados pelos m todos diretos para a determinao dos pontos crticos um m todo semi direto foi desenvolvido neste trabalho Os resultados obtidos na anlise de diferentes exemplos mostraram a adequao dos elementos finitos e dos m todos numricos implementados Os algoritmos de programao matemtica utilizados neste trabalho precisam dos gradientes da funo objetivo e das restries que s o calculadas com base nos gradientes das respostas da estrutura Partindo-se de equaes gerais vlidas para quaisquer elementos foram desenvolvidas expresses analticas que permitem o clculo exato das sensibilidades de elementos finitos isoparametricos formulados atravs do procedimento Lagrangiano Total O desenvolvimento e a implementao de expresses semelhantes para elementos mais complexos uma tarefa bastante rdua Por outro lado o m todo das diferenas finitas simples e genrico mas muito caro computacionalmente O m todo semi analtico mantm as vantagens da utilizao de diferenas finitas e possui um custo computacional baixo por m pode apresentar srios problemas de preciso Devido a estes motivos foi desenvolvido neste trabalho um procedimento para melhorar a qualidade das sensibilidades semi analticas de estruturas geometricamente n o lineares O procedimento baseado na diferenciao exata dos movimentos de corpo rgido do elemento utilizado Os resultados numricos obtidos demonstraram a sua eficcia

Inverse Problems in Engineering Mechanics II G.S. Dulikravich, Mana Tanaka, 2000-12-11 Inverse Problems are found in many areas of engineering mechanics and there are many successful applications e g in non destructive testing and characterization of material properties by ultrasonic or X ray

techniques thermography etc Generally speaking inverse problems are concerned with the determination of the input and the characteristics of a system given certain aspects of its output Mathematically such problems are ill posed and have to be overcome through development of new computational schemes regularization techniques objective functionals and experimental procedures Following the IUTAM Symposium on these topics held in May 1992 in Tokyo another in November 1994 in Paris and also the more recent ISIP 98 in March 1998 in Nagano it was concluded that it would be fruitful to gather regularly with researchers and engineers for an exchange of the newest research ideas The most recent Symposium of this series International Symposium on Inverse Problems in Engineering Mechanics ISIP2000 was held in March of 2000 in Nagano Japan where recent developments in inverse problems in engineering mechanics and related topics were discussed The following general areas in inverse problems in engineering mechanics were the subjects of ISIP2000 mathematical and computational aspects of inverse problems parameter or system identification shape determination sensitivity analysis optimization material property characterization ultrasonic non destructive testing elastodynamic inverse problems thermal inverse problems and other engineering applications The papers in these proceedings provide a state of the art review of the research on inverse problems in engineering mechanics and it is hoped that some breakthrough in the research can be made and that technology transfer will be stimulated and accelerated due to their publication *Applied Mechanics Reviews*, 1991 *Simulation of Material Processing: Theory, Methods and Application* Ken-ichiro Mori, 2001-01-01 This volume contains about 180 papers including seven keynotes presented at the 7th NUMIFORM Conference It reflects the state of the art of simulation of industrial forming processes such as rolling forging sheet metal forming injection moulding and casting

Computational Mechanics Zhenhan Yao, Mingwu Yuan, 2009-03-24 Computational Mechanics is the proceedings of the International Symposium on Computational Mechanics ISCM 2007 This conference is the first of a series created by a group of prominent scholars from the Mainland of China Hong Kong Taiwan and overseas Chinese who are very active in the field The book includes 22 full papers of plenary and semi plenary lectures and approximately 150 one page summaries

Introduction to Shape Optimization J. Haslinger, R. A. E. Mäkinen, 2003-01-01 The efficiency and reliability of manufactured products depend on among other things geometrical aspects it is therefore not surprising that optimal shape design problems have attracted the interest of applied mathematicians and engineers This self contained elementary introduction to the mathematical and computational aspects of sizing and shape optimization enables readers to gain a firm understanding of the theoretical and practical aspects so they may confidently enter this field Introduction to Shape Optimization Theory Approximation and Computation treats sizing and shape optimization comprehensively covering everything from mathematical theory existence analysis discretizations and convergence analysis for discretized problems through computational aspects sensitivity analysis numerical minimization methods to industrial applications Applications include contact stress minimization for elasto plastic bodies multidisciplinary optimization of an airfoil and shape

optimization of a dividing tube By presenting sizing and shape optimization in an abstract way the authors are able to use a unified approach in the mathematical analysis for a large class of optimization problems in various fields of physics Audience the book is written primarily for students of applied mathematics scientific computing and mechanics Most of the material is directed toward graduate students although a portion of it is suitable for senior undergraduate students Readers are assumed to have some knowledge of partial differential equations and their numerical solution as well as modern programming language such as C Fortran 90

Computer Aided Optimal Design: Structural and Mechanical Systems Carlos A. Mota Soares, 2012-12-06 This book contains the edited version of lectures and selected papers presented at the NATO ADVANCED STUDY INSTITUTE ON COMPUTER AIDED OPTIMAL DESIGN Structural and Mechanical Systems held in Tr6ia Portugal 29th June to 11th July 1986 and organized by CEMUL Center of Mechanics and Materials of the Technical University of Lisbon The Institute was attended by 120 participants from 21 countries including leading scientists and engineers from universities research institutions and industry and Ph D students Some participants presented invited and contributed papers during the Institute and almost all participated actively in discussions on scientific aspects during the Institute The Advanced Study Institute provided a forum for interaction among eminent scientists and engineers from different schools of thought and young reseachers The Institute addressed the foundations and current state of the art of essential techniques related to computer aided optimal design of structural and mechanical systems namely Vari ational and Finite Element Methods in Optimal Design Numerical Optimization Techniques Design Sensitivity Analysis Shape Optimal Design Adaptive Finite Element Methods in Shape Optimization CAD Technology Software Development Techniques Integrated Computer Aided Design and Knowledge Based Systems Special topics of growing importance were also pre sented

Boundary Elements and other Mesh Reduction Methods XLII Cheng, A. H-D, Tadeu, A., 2019-09-13 Originating from the 42nd conference on Boundary Elements and other Mesh Reduction Methods BEM MRM the research presented in this book consist of high quality papers that report on advances in techniques that reduce or eliminate the type of meshes associated with such methods as finite elements or finite differences

Design Sensitivity Analysis and Optimization of Electromagnetic Systems II Han Park, 2018-08-27 This book presents a comprehensive introduction to design sensitivity analysis theory as applied to electromagnetic systems It treats the subject in a unified manner providing numerical methods and design examples The specific focus is on continuum design sensitivity analysis which offers significant advantages over discrete design sensitivity methods Continuum design sensitivity formulas are derived from the material derivative in continuum mechanics and the variational form of the governing equation Continuum sensitivity analysis is applied to Maxwell equations of electrostatic magnetostatic and eddy current systems and then the sensitivity formulas for each system are derived in a closed form an integration along the design interface The book also introduces the recent breakthrough of the topology optimization method which is accomplished by coupling the level set method and continuum design sensitivity This

topology optimization method enhances the possibility of the global minimum with minimised computational time and in addition the evolving shapes during the iterative design process are easily captured in the level set equation Moreover since the optimization algorithm is transformed into a well known transient analysis algorithm for differential equations its numerical implementation becomes very simple and convenient Despite the complex derivation processes and mathematical expressions the obtained sensitivity formulas are very straightforward for numerical implementation This book provides detailed explanation of the background theory and the derivation process which will help readers understand the design method and will set the foundation for advanced research in the future

Approximation, Optimization, and Computing
 Alan Greenwell Law, Chung-lie Wang, 1990 This volume consists of 101 papers in the areas of approximation optimization and computing and applications Under the sponsorship of IMACS The International Association for Mathematics and Computers in Simulation it represents a collaborative venture initiated in 1986 between the Dalian University of Technology and the University of Regina A primary goal of the project was to encourage research papers reflecting emerging directions within theory and applications Covered are the following analytic or discrete approximations optimization applications deterministic or stochastic processes programming and applications of theory or techniques in engineering or other sciences

Mathematical Modeling and Optimization of Complex Structures Pekka Neittaanmäki, Sergey Repin, Tero Tuovinen, 2015-10-07 This volume contains selected papers in three closely related areas mathematical modeling in mechanics numerical analysis and optimization methods The papers are based upon talks presented on the International Conference for Mathematical Modeling and Optimization in Mechanics held in Jyväskylä Finland March 6 7 2014 dedicated to Prof N Banichuk on the occasion of his 70th birthday The articles are written by well known scientists working in computational mechanics and in optimization of complicated technical models Also the volume contains papers discussing the historical development the state of the art new ideas and open problems arising in modern continuum mechanics and applied optimization problems Several papers are concerned with mathematical problems in numerical analysis which are also closely related to important mechanical models The main topics treated include Computer simulation methods in mechanics physics and biology Variational problems and methods minimization algorithms Optimal control problems with distributed and discrete control Shape optimization and shape design problems in science and engineering Sensitivity analysis and parameters optimization of complex systems

Structural Sensitivity Analysis and Optimization 2 K. K. Choi, Nam-Ho Kim, 2006-12-22 Extensive numerical methods for computing design sensitivity are included in the text for practical application and software development The numerical method allows integration of CAD FEA DSA software tools so that design optimization can be carried out using CAD geometric models instead of FEA models This capability allows integration of CAD CAE CAM so that optimized designs can be manufactured effectively

Computer Aided Optimum Design of Structures C. A. Brebbia, Santiago Hernández, 1989

Computational Methods in Applied Sciences Ch Hirsch, Jacques

Periaux,E. Oñate,1992 The European Computational Fluid Dynamics Conference and the European Conference on Numerical Methods in Engineering are the initiative of national Scientific Societies of many countries in Europe engaged in these fields The 28 papers in this volume give an extensive review on selected topics pertaining to basic methodologies scientific developments and industrial applications in fluid dynamics in structural mechanics and other engineering applications This multidisciplinary volume brings together specialists in a wide range of engineering activities who employ common analytical and experimental methods in their research The contents are of world wide interest and will help to stimulate future research and analysis in this broad field *Computational Material Modeling* Ahmed Khairy Noor,A. Needleman,1994

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