

*Modeling and Simulation in
Science, Engineering and Technology*

Numerical Methods in Sensitivity Analysis and Shape Optimization

*Emmanuel Laporte
Patrick Le Tallec*

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Numerical Methods In Sensitivity Analysis And Shape Optimization

Ken-ichiro Mori



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.

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 elastoplastic 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. *Applied Mechanics Reviews*, 1991. *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. Computational Mechanics Zhenhan Yao, Mingwu Yuan, 2009-03-24 Computational Mechanics is the Proceedings of the 2007 International Symposium on Computational Mechanics ISCM held July 30 August 1 2007 in Beijing. The book includes 22 full papers of plenary and semi plenary lectures and approximately 150 one page summaries. This conference is the first of a series that is 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. This conference series will be held alternately in the Mainland of China Hong Kong Macao Taiwan and overseas countries.

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.

Sensitivity analysis and shape optimization of geometrically non-linear structures, 2000 Este trabalho prop e uma metodologia para a otimizac o de forma de estruturas geometricamente n o lineares. O objetivo desta metodologia e evitar os problemas de instabilidade apresentados por estruturas otimizadas de acordo com a formula o cl ssica. Ela foi implementada para problemas bidimensionais e os resultados obtidos na otimizac o de diferentes estruturas demonstraram o seu sucesso. Utilizando-se conceitos de modelagem geom trica a forma da estrutura e definida atrav s das curvas de seu contorno. Assim a representa o param trica de curvas e a definic o destas em fun o de um conjunto de pontos de interpola o pontos chave s o discutidas detalhadamente. A nfase dada e a interpola o atrav s de B splines devido a sua grande flexibilidade. O problema de otimizac o e definido com base no modelo geom trico e as vari veis de projeto s o as coordenadas dos pontos chave. A simetria da estrutura e garantida atrav s da liga o de vari veis. A estrutura analisada e dividida em elementos isoparametricos planos. Assim antes de realizar a an lise e necess rio discretizar a estrutura em um conjunto de elementos finitos. Para realizar esta tarefa foram implementados diferentes algoritmos de gera o de malhas tanto estruturadas quanto n o estruturadas. O m todo de Newton Raphson e utilizado para determinar a configura o de equil brio e diferentes m todos podem ser aplicados para determinar os pontos cr ticos. Devido aos problemas de converg ncia apresentados pelos m todos diretos para a determina o dos pontos cr ticos um m todo semi direto foi desenvolvido neste trabalho. Os resultados obtidos na an lise de

diferentes exemplos mostraram a adequação dos elementos finitos e dos métodos numéricos implementados. Os algoritmos de programação matemática utilizados neste trabalho precisam dos gradientes da função objetivo e das restrições que são calculadas com base nos gradientes das respostas da estrutura. Partindo-se de equações gerais válidas para quaisquer elementos foram desenvolvidas expressões analíticas que permitem o cálculo exato das sensibilidades de elementos finitos isoparamétricos formulados através do procedimento Lagrangiano Total. O desenvolvimento e a implementação de expressões semelhantes para elementos mais complexos é uma tarefa bastante árdua. Por outro lado, o método das diferenças finitas simples é genérico, mas muito caro computacionalmente. O método semi-analítico mantém as vantagens da utilização de diferenças finitas e possui um custo computacional baixo, por não pode apresentar sérios problemas de precisão. Devido a estes motivos foi desenvolvido neste trabalho um procedimento para melhorar a qualidade das sensibilidades semi-analíticas de estruturas geometricamente não lineares. O procedimento baseado na diferença exata dos movimentos de corpo rígido do elemento utilizado. Os resultados numéricos obtidos demonstraram a sua eficácia.

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 consists 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.

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.

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

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

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

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 Shape optimization of valve geometry with contact analysis, Sensitivity Analysis and Optimization with Numerical Methods, Winter Annual Meeting of the ASME, Nov. 25-30 1990, v 115, p 71-78 A. D. Belegundu, 1990 **ASME Technical Papers**, 1998 *Sensitivity Analysis and Optimization with Numerical Methods* American Society of Mechanical Engineers. Winter Annual Meeting, 1990 *Multi-scale Computational Techniques for Design of Polycrystalline Materials* Veeraraghavan Sundararaghyavan, 2007 Microstructures play an important role in controlling distribution of properties in engineering materials It is possible to develop components with tailored distribution of properties such as strength and stiffness by controlling microstructure evolution during the manufacturing process When forming metallic components by imposing large deformations mechanisms such as slip and lattice rotation drive formation of texture in the underlying polycrystalline microstructure Such microstructural changes affect the final distribution of material properties in the component By carefully designing the imposed deformation one could potentially tailor the microstructure and obtain desired property distributions This thesis focuses on development of novel computational strategies for designing deformation processes to realize materials with desired properties The techniques presented are an interplay of several new tools developed recently such as reduced order modeling graphical cross plots statistical learning microstructure homogenization and multi scale sensitivity analysis The primary outcomes of this thesis are listed below Development of reduced order representations and graphical methodologies for representing process property texture relationships Development of adaptive reduced order optimization techniques for identification of processing paths that lead to desirable microstructure sensitive properties Development of homogenization techniques for predicting microstructure evolution in large deformation processes Development of multi scale sensitivity analysis of poly crystalline material deformation for optimizing microstructure sensitive properties during industrial forming processes The framework for design of polycrystalline microstructures leads to increased product yield in industrial forming processes and simultaneously allows control distribution of properties such as stiffness and strength in forged products Multiscale design problems leading to billions of unknowns have been solved using parallel computing techniques The computational framework can be readily used for selecting optimal processing paths for achieving desired properties The methodology developed is a fundamental effort at providing detailed deformation process design solutions needed for controlling properties of performance critical hardware components in automotive structural and aerospace applications Abstract

Structural Sensitivity Analysis and Optimization 1 Kyung K. Choi, Nam-Ho Kim, 2004-12-08 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

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