Adaptive Finite Element Methods For Differential Equations By Wolfgang Bangerth | fd723c497db952ee2259db093d179357

Constitutive Models for RubberAdaptive Finite Element Methods for Elliptic EquationsAdaptive Finite Element Methods for the Euler EquationsAdaptive Finite Element Methods for Parabolic Partial Differential EquationsMulti-level Adaptive Finite Element MethodsP-adaptive and Automatic Hp-adaptive Finite Element Methods for Elliptic Partial Differential EquationsAdaptive Finite Element Methods for Parameter Identification ProblemsAdaptive Finite Element Methods for the Compressible Euler EquationsMultiscale, Nonlinear and Adaptive ApproximationAdaptive Finite Element Methods for Contact Problems Embedded in a Fictitious DomainDesign of Adaptive Finite Element SoftwareUnified Multilevel Adaptive Finite Element Methods for Elliptic ProblemsError-controlled Adaptive Finite Elements in Solid MechanicsAdaptive Finite Element Methods for the Compressible Euler EquationsAdaptive Finite Element Methods for Optimal Control ProblemsConvergence of Adaptive Finite Element MethodsAdaptive Finite Element Methods for the Helmholtz Equation in Exterior DomainsAdaptive Finite Element Methods for Differential EquationsLarge-Scale Structures in Acoustics and ElectromagneticsAdaptive Finite Element Methods for Optimization ProblemsThe Finite Element Method: Its Basis and FundamentalsThe Mathematical Theory of Finite Element MethodsAn Adaptive Finite Element Method for High Speed FlowsMultiscale and Adaptivity: Modeling, Numerics and ApplicationsA Posteriori Error Estimation Techniques for Finite Element MethodsHigher-Order Finite Element MethodsFinite Element Analysis with Error EstimatorsAdaptive Finite Element Solution Algorithm for the Euler EquationsAdaptive Finite Element Methods for ShellsLocal Space-time Adaptive Finite Element Methods for the Wave Equation on Unbounded DomainsAdaptive Finite and Boundary Element MethodsInexact Adaptive Finite Element Methods for Elliptic PDE Eigenvalue ProblemsAdaptive Finite Element Methods for Computing Nonstationary Incompressible FlowsAdaptive Finite Element Methods for the Unsteady Maxwell's EquationsAdaptive Finite Element Methods for Flow Problems in Regions with Moving BoundariesComputing with hp-ADAPTIVE FINITE ELEMENTSAdaptive Finite Element Methods for Multiscale Partial Differential EquationsAdaptive Finite Elements in Linear and Nonlinear Solid and Structural MechanicsAdaptive Finite Element Methods for Reactive Compressible FlowAdaptive Finite Element Methods for Parameter Identification Problems

The authors discuss a finite element method for solving initial-boundary value problems for vector systems of partial differential equations in one space dimension and time. The method automatically adjusts the computational mesh as the solution evolves in time so as to approximately minimize the local discretization error. They are thus able to calculate accurate solutions with fewer elements than would be necessary with a uniform mesh. This overall method contains two distinct steps: a solution step and a mesh selection step. They solve the partial differential equations using a finite element-Galerkin method on trapezoidal space-time-elements with either piecewise linear or cubic Hermits polynomial approximations. A variety of mesh selection strategies are discussed and analyzed. Results are presented for several computational examples.

The work deals with a systematic theoretical and problem-oriented treatment of fundamental topics in the wide area of error-controlled adaptive finite element methods for analyzing engineering structures with elastic and inelastic material behavior applied to engineering structures. Different types of error estimators are presented from both mathematical and engineering points of views: global estimators and goal-oriented estimators based on duality techniques, controlling h-, p-, and hp-adaptivity. Special features are: combined model and discretization adaptivity for thin-walled structures, hierarchic modeling in elasticity and related hp-adaptivity, error estimators of constitutive equations, adequate mesh refinement techniques and error-controlled adaptive elastic-plastic analysis of contact problems. The benefits are seen in new methods and results of leading researches in the field which provide deeper insight into recent developments of a posteriori error analysis and adaptivity.

This text aims to enable the experience accumulated by engineers and the research community in materials science, continuum mechanics and applied mathematics to be shared. In this way, the design and analysis of rubber components using the Finite Element Method should be enhanced.

The book of invited articles offers a collection of high-quality papers in selected and highly topical areas of Applied and Numerical Mathematics and Approximation Theory which have some connection to Wolfgang Dahmen's scientific work. On the occasion of his 60th birthday, leading experts have contributed survey and research papers in the areas of Nonlinear Approximation Theory, Numerical Analysis of Partial Differential and Integral Equations, Computer-Aided Geometric Design, and Learning Theory. The main focus and common theme of all the articles in this volume is the mathematics building the foundation for most efficient numerical algorithms for simulating complex phenomena.

Based on the author's Ph. D. thesis (Massachusetts Institute of Technology).

The Sixth Edition of this influential best-selling book delivers the most up-to-date and comprehensive text and reference yet on the basis of the finite element method (FEM) for all engineers and mathematicians. Since the appearance of the first edition 38 years ago, The Finite Element Method provides arguably the most authoritative introductory text to the method, covering the latest developments and approaches in this dynamic subject, and is amply supplemented by exercises, worked solutions and computer algorithms. • The classic FEM text, written by the subject's leading authors • Enhancements include more worked examples and exercises • With a new chapter on automatic mesh generation and added materials on shape function development and the use of higher order elements in solving elasticity and field problems Active research has shaped The Finite Element Method into the pre-eminent tool for the modelling of physical systems. It maintains the comprehensive style of earlier editions, while presenting the systematic development for the solution of problems modelled by linear differential equations. Together with the second and third self-contained volumes (0750663219 and 0750663227), The Finite Element Method Set (0750664312) provides a formidable resource covering the theory and the application of FEM, including the basis of the method, its application to advanced solid and structural mechanics and to computational fluid dynamics. The classic introduction to the finite element method, by two of the subject's leading authors Any professional or student of engineering involved in understanding the computational modelling of physical systems will inevitably use the techniques in this key text

With a focus on 1D and 2D problems, the first volume of Computing with hp-ADAPTIVE FINITE ELEMENTS prepared readers for the concepts and logic governing 3D code and implementation. Taking the next step in hp technology, Volume II Frontiers: Three-Dimensional Elliptic and Maxwell Problems with Applications presents the theoretical foundations of the 3D hp algorithm and provides numerical results using the 3Dhp code developed by the authors and their colleagues. The first part of the book focuses on fundamentals of the 3D theory of hp methods as well as issues that arise when the code is implemented. After a review of boundary-value problems, the book examines exact hp sequences, projection-based interpolation, and De Rham diagrams. It also presents the 3D version of the automatic hp-adaptivity package, a two-grid solver for highly anisotropic hp meshes and goal-oriented Krylov iterations, and a parallel implementation of the 3D code. The second part explores several recent projects in which the 3Dhp code was used and illustrates how these applications have greatly driven the development of 3D hp technology. It encompasses acoustic and electromagnetic (EM) scattering problems, an analysis of complex structures with thin-walled components, and challenging simulations of logging tools. The book concludes with a look at the future of hp methods. Spearheaded by a key developer of this technology with more than 20 years of research in the field, this self-contained, comprehensive resource will help readers overcome the difficulties in coding hp-adaptive elements.

A posteriori error estimation techniques are fundamental to the efficient numerical solution of PDEs arising in physical and technical applications. This book gives a unified approach to these techniques and guides graduate students, researchers, and practitioners towards understanding, applying and developing self-adaptive discretization methods.

This book focuses on computational methods to determine the dynamics of large-scale electromagnetic, acoustic, and mechanical systems, including those with many substructures and characterized by an extended range of scales. Examples include large naval and maritime vessels, aerospace vehicles, and densely packed microelectronic and optical integrated circuits (VLSI). The interplay of time and frequency-domain computational and experimental procedures was addressed, emphasizing their relationship and synergy, and indicating mathematics research opportunities.

These Lecture Notes have been compiled from the material presented by the second author in a lecture series ('Nachdiplomvorlesung') at the Department of Mathematics of the ETH Zurich during the summer term 2002. Concepts of 'self adaptivity' in the numerical solution of differential equations are discussed with emphasis on Galerkin finite element methods. The key issues are a posteriori er ror estimation and automatic mesh adaptation. Besides the traditional approach of energy-norm error control, a new duality-based technique, the Dual Weighted Residual method (or shortly D WR method) for goal-oriented error estimation is discussed in detail. This method aims at economical computation of arbitrary quantities of physical interest by properly adapting the computational mesh. This is typically required in the design cycles of technical applications. For example, the drag coefficient of a body immersed in a viscous flow is computed, then it is minimized by varying certain control parameters, and finally the stability of the resulting flow is investigated by solving an eigenvalue problem. 'Goal-oriented' adaptivity is designed to achieve these tasks with minimal cost. The basics of the DWR method and various of its applications are described in the following survey articles: R. Rannacher [114], Error control in finite element computations. In: Proc. of Summer School Error Control and Adaptivity in Scientific Computing (H. Bulgak and C. Zenger, eds), pp. 247-278. Kluwer Academic Publishers, 1998. M. Braack and R. Rannacher [42], Adaptive finite element methods for low Mach-number flows with chemical reactions.

This book is a collection of lecture notes for the CIME course on "Multiscale and Adaptivity: Modeling, Numerics and Applications," held in Cetraro (Italy), in July 2009. Complex systems arise in several physical, chemical, and biological processes, in which length and time scales may span several orders of magnitude. Traditionally, scientists have focused on methods that are particularly applicable in only one regime, and knowledge of the system on one scale has been transferred to another scale only indirectly. Even with modern computer power, the complexity of such systems precludes their being treated directly with traditional tools, and new mathematical and computational instruments have had to be developed to tackle such problems. The outstanding and internationally renowned lecturers, coming from different areas of Applied Mathematics, have themselves contributed in an essential way to the development of the theory and techniques that constituted the subjects of the courses.

In this thesis we introduce a discontinuous Galerkin method for the numerical solution of hyperbolic conversation laws, as for example the compressible Euler equations of gas dynamics. Based on this finite element method, we develop an adaptive algorithm for the efficient computation of physically relevant quantities of the solution. This includes a posteriori error estimation of the error in the computed quantity as well as adaptive mesh design specifically tailored to the efficient computation of this quantity. We illustrate this approach by several different hyperbolic problems in combination with various different target quantities, including the efficient computation of drag and lift coefficients of airfoils immersed in inviscid compressible gas flows.

Finite Element Methods are used for numerous engineering applications where numerical solutions of partial differential equations are needed. As computers can now deal with the millions of parameters used in these methods, automatic error estimation and automatic adaptation of the utilised method (according to this error estimation), has become a hot research topic. This text offers comprehensive coverage of this new field of automatic adaptation and error estimation, bringing together the work of eight outstanding researchers in this field who have completed a six year national research project within the German Science Foundation. The result is a state-of-the-art work in true reference style. Each chapter is self-contained and covers theoretical, algorithmic and software presentations as well as solved problems. A main feature consists of several carefully elaborated benchmarks of 2D- and 3D-applications. * First book to go beyond the Finite Element Method in itself * Covers material from a new research area * Presents benchmarks of 2D- and 3D- applications * Fits with the new trend for genetic strategies in engineering

This key text is written for senior undergraduate and graduate engineering students. It delivers a complete introduction to finite element methods and to automatic adaptation (error estimation) that will enable students to understand and use FEA as a true engineering tool. It has been specifically developed to be accessible to non-mathematics students and provides the only complete text for FEA with error estimators for non-mathematicians. Error estimation is taught on nearly half of all FEM courses for engineers at senior undergraduate and postgraduate level; no other existing textbook for this market covers this topic. The only introductory FEA text with error estimation for students of engineering, scientific computing and applied mathematics Includes source code for creating and proving FEA error estimators

The finite element method has always been a mainstay for solving engineering problems numerically. The most recent developments in the field clearly indicate that its future lies in higher-order methods, particularly in higher-order hp-adaptive schemes. These techniques respond well to the increasing complexity of engineering simulations and

A rigorous and thorough mathematical introduction to the subject; A clear and concise treatment of modern fast solution techniques such as multigrid and domain decomposition algorithms; Second edition contains two new chapters, as well as many new exercises; Previous edition sold over 3000 copies worldwide

An adaptive finite element procedure is developed for the transient analysis of nonlinear shells. The scheme is an h-method which employs fission and fusion. Criteria based on incremental work and deviation of the bilinear finite element approximation to the shell from a Kirchhoff-Love surface are used as criteria for adaptivity. The example problems show that the adaptive schemes are capable of achieving substantial improvements in accuracy for a given computational effort. They include both material and geometric nonlinearities and local and global buckling. In order to formulate an r-adaptive method, the conservation laws, the constitutive equations, and the equation of state for path-dependent materials are formulated for an arbitrary Lagrangian-Eulerian description. Both geometrical and material nonlinearities are included in this setting. Keywords: Finite elements, Adaptive meshes, Shells.

During the last years, scientific computing has become an important research branch located between applied mathematics and applied sciences and engineering. Highly efficient numerical methods are based on adaptive methods, higher order discretizations, fast linear and non-linear iterative solvers, multi-level algorithms, etc. Such methods are integrated in the adaptive finite element software ALBERTA. It is a toolbox for the fast and flexible implementation of efficient software for real life applications, based on modern algorithms. ALBERTA also serves as an environment for improving existent, or developing new numerical methods in an interplay with mathematical analysis and it allows the direct integration of such new or improved methods in existing simulation software.

In this dissertation, we formulate and implement p-adaptive and hp-adaptive finite element methods to solve elliptic partial differential equations. The main idea of the work is to use elements of high degrees solely (p-adaptive) or in combination with elements of small size (hp-adaptive) to better capture the behavior of the solution. In implementing the idea, we deal with different aspects of building an adaptive finite element method, such as defining basis functions, developing algorithms for adaptive meshing procedure and formulating a posteriori error estimates and error indicators. The basis functions used in this work are regular nodal basis functions and special basis functions defined for elements with one or more edges of higher degree transition elements). It is proved that with our construction of these basis functions, the finite element space is well-defined and C0. Several algorithms are developed for different scenarios of the adaptive meshing procedure, namely, p-refinement, p-unrefinement and hp-refinement. They all follow the 1-irregular rule and 2-neighbor rule motivated by [Bank and Sherman, 1983 - MR751598]. These rules help to limit the number of special cases and maintain the sparsity of the stiffness matrix, and thus to simplify the implementation and reduce the cost of calculation. The work of formulating a posteriori error estimates and error indicators is the core of this dissertation. Our error estimates and error indicators are based on the derivative recovery technique proposed by [Bank and Xu, 2003 - MR2034616, MR2034617] and Bank et al., 2007 - MR2346369]. Using the information in formulating the error indicators, we define a hp-refinement indicator which can be utilized to decide whether a given element should be refined in h or in p. Numerical results show that the combination of the two indicators helps automatic hp-refinement to create optimal meshes that demonstrate exponential rate of convergence. In this dissertation, we also consider hp-adaptive and domain decomposition when they are combined using the parallel adaptive meshing paradigm developed by [Bank and Holst, 2000 - MR1797889]. Numerical experiments demonstrate that the paradigm scales up to at least 256 processors (maximum size of our experiments) and with nearly 200 millions degrees of freedom.