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A Vector Element-Free Galerkin Method for Waveguide Eigenvalue Problems Meshless Element Free Galerkin Method and Finite Difference Method in One-dimensional Boundary Value Problems Mesh Free Methods Curve and Surface Fitting Nonlinear Solid Mechanics Analysis Using the Parallel Selective Element-free Galerkin Method An Introduction to Meshfree Methods and Their Programming Differential Equations in Engineering Meshless Methods in Solid Mechanics Element Free Galerkin Method in Structural Mechanics Nodal Integration of the Element-free Galerkin Method and Related Topics in the Stability of Computational Mechanics Meshfree Methods Meshless Analysis of an Improved Element-free Galerkin Method for Linear and Nonlinear Elliptic Problems *Project Supported by the National Natural Science Foundation of China (Grant No. 11471063), the Chongqing Research Program of Basic Research and Frontier Technology, China (Grant No. Cstc2015jcyjBX0083), and the Educational Commission Foundation of Chongqing City, China (Grant No. KJ1600330). Crack Propagation by Element-Free Galerkin Methods Numerial Development of an Improved Element-free Galerkin Method for Engineering Analysis Finite Elements and Approximation Introduction to Interval Computation Nodal Discontinuous Galerkin Methods Adaptive Element Free Galerkin Method for 2D Stress Analysis Meshfree Methods for Partial Differential Equations The Application of Meshless Element Free Galerkin (EFG) Method in Burgers' Equation Discontinuous Galerkin Methods Numerical Methods for Energy Applications Element Free Galerkin Method for Heat Transfer Obstacle Problems in Mathematical Physics Error Estimates for Advanced Galerkin Methods Application of the Element Free Galerkin Method to Elastic Rods The Mathematical Theory of Finite Element Methods The Meshless Local Petrov-Galerkin (MLPG) Method Meshfree Methods for Partial Differential Equations IV Simulating Large Deformation Processes Using an Explicit Element-free Galerkin Method Everything You Always Wanted to Know about the Element-Free Galerkin Method, and More Improved Element-Free Galerkin Method for Electromagnetic NDE Model (Preprint). Discontinuous Galerkin Method Element Free Galerkin Method Based on Moving Least Square Approximants Quadrature-free Implementation of Discontinuous Galerkin Method for Hyperbolic Equations Discontinuous Galerkin Methods for Solving Elliptic and Parabolic Equations Meshfree Particle Methods Modeling Shallow Water Flows Using the Discontinuous Galerkin Method An Introduction to Element-Based Galerkin Methods on Tensor-Product Bases Analysis of Elastoplasticity Problems Using an Improved Complex Variable Element-free Galerkin Method*Project Supported by the National Natural Science Foundation of China (Grant Nos. 11171208 and U1433104).

A powerful tool for the approximate solution of differential equations, the finite element is extensively used in industry and research. This book offers students of engineering and physics a comprehensive view of the principles involved, with numerous illustrative examples and exercises. Starting with continuum boundary value problems and the need for numerical discretization, the text examines finite difference methods, weighted residual methods in the context of continuous trial functions, and piecewise defined trial functions and the finite element method. Additional topics include higher order finite element approximation, mapping and numerical integration, variational methods, and partial discretization and time-dependent problems. A survey of generalized finite elements and error estimates concludes the text. The purpose of this book is to reveal the foundations and major features of several basic methods for curve and surface fitting that are currently in use. 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 This book introduces the reader to solving partial differential equations (PDEs) numerically using element-based Galerkin methods. Although it draws on a solid theoretical foundation (e.g. the theory of interpolation, numerical integration, and function spaces), the book's main focus is on how to build the method, what the resulting matrices look like, and how to write algorithms for coding Galerkin methods. In addition, the spotlight is on tensor-product bases, which means that only line elements (in one dimension), quadrilateral elements (in two dimensions), and cubes (in three dimensions) are considered. The types of Galerkin methods covered are: continuous Galerkin methods (i.e., finite/spectral elements), discontinuous Galerkin methods, and hybridized discontinuous Galerkin methods using both nodal and modal basis functions. In addition, examples are included (which can also serve as student projects) for solving hyperbolic and elliptic partial differential equations, including both scalar PDEs and systems of equations. A class of finite element methods, the Discontinuous Galerkin Methods (DGM), has been under rapid development recently and has found its use very quickly in such diverse applications as aeroacoustics, semi-conductor device simula tion, turbomachinery, turbulent flows, materials processing, MHD and plasma simulations, and image processing. While there has been a lot of interest from mathematicians, physicists and engineers in DGM, only scattered information is available and there has been no prior effort in organizing and publishing the existing volume of knowledge on this subject. In May 24-26, 1999 we organized in Newport (Rhode Island, USA), the first international symposium on DGM with equal emphasis on the theory, numerical implementation, and applications. Eighteen invited speakers, lead ers in the field, and thirty-two contributors presented various aspects and addressed open issues on DGM. In this volume we include forty-nine papers presented in the Symposium as well as a survey paper written by the organiz ers. All papers were peer-reviewed. A summary of these papers is included in the survey paper, which also provides a historical perspective of the evolution of DGM and its relation to other numerical methods. We hope this volume will become a major reference in this topic. It is intended for students and researchers who work in theory and application of numerical solution of convection dominated partial differential equations. The papers were written with the assumption that the reader has some knowledge of classical finite elements and finite volume methods. Meshfree methods for the solution of partial differential equations gained much attention in recent years, not only in the engineering but also in the mathematics community. One of the reasons for this development is the fact that meshfree discretizations and particle models are often better suited to cope with geometric changes of the domain of interest, e.g. free surfaces and large deformations, than classical discretization techniques such as finite differences, finite elements or finite volumes. Another obvious advantage of meshfree discretizations is their independence of a mesh so that the costs of mesh generation are eliminated. Also, the treatment of time-dependent PDEs from a Lagrangian point of view and the coupling of particle models and continuous models gained enormous interest in recent years from a theoretical as well as from a practial point of view. This volume consists of articles which address the different meshfree methods (SPH, PUM, GFEM, EFGM, RKPM etc.) and their application in applied mathematics, physics and engineering. The finite difference method (FDM) hasbeen used tosolve differential equation systems for centuries. The FDM works well for problems of simple geometry and was widely used before the invention of the much more efficient, robust finite element method (FEM). FEM is now widely used in handling problems with complex geometry. Currently, we are using and developing even more powerful numerical techniques aiming to obtain more accurate approximate solutions in a more convenient manner for even more complex systems. The meshfree or meshless method is one such phenomenal development in the past decade, and is the subject of this book. There are many MFree methods proposed so far for different applications. Currently, three monographs on MFree methods have been published. Mesh Free Methods, Moving Beyond the Finite Element Method d by GR Liu (2002) provides a systematic discussion on basic theories, fundamentals for MFree methods, especially on MFree weak-form methods. It provides a comprehensive record of well-known MFree methods and the wide coverage of applications of MFree methods to problems of solids mechanics (solids, beams, plates, shells, etc.) as well as fluid mechanics. The Meshless Local Petrov-Galerkin (MLPG) Method d by Atluri and Shen (2002) provides detailed discussions of the meshfree local Petrov-Galerkin (MLPG) method and itsvariations. Formulations and applications of MLPG are well addressed in their book. This book provides a thorough guide to the use of numerical methods in energy systems and applications. It presents methods for analysing engineering applications for energy systems, discussing finite difference, finite element, and other advanced numerical methods. Solutions to technical problems relating the application of these methods to energy systems are also thoroughly explored. Readers will discover diverse perspectives of the contributing authors and extensive discussions of issues including: • a wide variety of numerical methods concepts and related energy systems applications;• systems equations and optimization, partial differential equations, and finite difference method;• methods for solving nonlinear equations, special methods, and their mathematical implementation in multi-energy sources;• numerical investigations of electrochemical fields and devices; and• issues related to numerical approaches and optimal integration of energy consumption. This is a highly informative and carefully presented book, providing scientific and academic insight for readers with an interest in numerical methods and energy systems. The element-free Galerkin (EFG) method is a mesh-free method for solving solid mechanics problems with an approximation based only on nodes. It is developed here for linear elastic fracture problems. Smoothing of mesh-free approximations near nonconvex boundaries is done by three methods: (1) the diffraction method, in which the nodal domain of influence wrapped a short distance around a boundary, (2) the transparency method, which is described only for cracks, yields continuous approximations by gradually severing the domains of influence near crack tips, and (3) the 'see-through' method, or continuous line criterion, which does not enforce a discontinuity or crack if the tip is within the domain of influence. Two methods for enriching EFG approximations for linear elastic fracture problems are described: extrinsic enrichment involves adding the form of the solution to the trial function; for intrinsic enrichment, the EFG basis is expanded to include terms from the near tip crack solution. Several problems are solved to illustrate the effectiveness of EFG crack propagation with smoothing and enrichment. Mesh based methods such as FEM has achieved a remarkable success in solving many engineering and science problems. However, it is widely known that the solution accuracy of these methods is largely depends on the quality of mesh generated. This becomes a serious problem when the mesh becomes distorted or changes with time. Moreover, the generation of higher order shape functions is also difficult for these methods. Due to these problems, mesh based methods are not well suited for certain types of problems such as strongly non-linear heat transfer and growth under thermo-elastic loading, etc. To overcome these problems, meshfree methods have been emerged as new computational tool. Element free Galerkin method (EFGM) is one of them. Although, a lot of literature exists on meshfree methods including few books in the area of solid mechanics, but not much literature exists in the area of heat transfer. Only few research papers are available on heat transfer using meshfree methods. Therefore, this monograph will not only provide the applications of EFGM in heat transfer but also provides the formulations along with its implementation methodology. A discontinuous Galerkin formulation that avoids the use of discrete quadrature formulas is described and applied to linear and nonlinear test problems in one and two space dimensions. This approach requires less computational time and storage than conventional implementations but preserves the compactness and robustness inherent in the discontinuous Galerkin method. Test problems include the linear and nonlinear one-dimensional scalar advection of smooth initial value problems that are discretized by using unstructured grids with varying degrees of smoothness and regularity, and two-dimensional linear Euler solutions on unstructured grids. This monograph provides a compendium of established and novel error estimation procedures applied in the field of Computational Mechanics. It also includes detailed derivations of these procedures to offer insights into the concepts used to control the errors obtained from employing Galerkin methods in finite and linearized hyperelasticity. The Galerkin methods introduced are considered advanced methods because they remedy certain shortcomings of the well-established finite element method, which is the archetypal Galerkin (mesh-based) method. In particular, this monograph focuses on the systematical derivation of the shape functions used to construct both Galerkin mesh-based and meshfree methods. The mesh-based methods considered are the (conventional) displacement-based, (dual-)mixed, smoothed, and extended finite element methods. In addition, it introduces the element-free Galerkin and reproducing kernel particle methods as representatives of a class of Galerkin meshfree methods. Including illustrative numerical examples relevant to engineering with an emphasis on elastic fracture mechanics problems, this monograph is intended for students, researchers, and practitioners aiming to increase the reliability of their numerical simulations and wanting to better grasp the concepts of Galerkin methods and associated error estimation procedures. The aim of this research monograph is to present a general account of the applicability of elliptic variational inequalities to the important class of free boundary problems of obstacle type from a unifying point of view of classical Mathematical Physics. The first part of the volume introduces some obstacle type problems which can be reduced to variational inequalities. Part II presents some of the main aspects of the theory of elliptic variational inequalities, from the abstract hilbertian framework to the smoothness of the variational solution, discussing in general the properties of the free boundary and including some results on the obstacle Plateau problem. The last part examines the application to free boundary problems, namely the lubrication-cavitation problem, the elastoplastic problem, the Signorini (or the boundary obstacle) problem, the dam problem, the continuous casting problem, the electrochemical machining problem and the problem of the flow with wake in a channel past a profile. This book covers the fundamentals of continuum mechanics, the integral formulation methods of continuum problems, the basic concepts of finite element methods, and the methodologies, formulations, procedures, and applications of various meshless methods. It also provides general and detailed procedures of meshless analysis on elastostatics, elastodynamics, non-local continuum mechanics and plasticity with a large number of numerical examples. Some basic and important mathematical methods are included in the Appendixes. For readers who want to gain knowledge through hands-on experience, the meshless programs for elastostatics and elastodynamics are provided on an included disc. Differential Equations in Engineering: Research and Applications describes advanced research in the field of the applications of differential equations in engineering and the sciences, and offers a sound theoretical background, along with case studies. It describes the advances in differential equations in real life for engineers. Along with covering many advanced differential equations and explaining the utility of these equations, the book provides a broad understanding of the use of differential equations to solve and analyze many real-world problems, such as calculating the movement or flow of electricity, the motion of an object to and from, like a pendulum, or explaining thermodynamics concepts by making use of various mathematical tools, techniques, strategies, and methods in applied engineering. This book is written for researchers and academicians, as well as for undergraduate and postgraduate students of engineering. Replacing the Traditional Physical Model Approach Computational models offer promise in improving the modeling of shallow water flows. As new techniques are considered, the process continues to change and evolve. Modeling Shallow Water Flows Using the Discontinuous Galerkin Method examines a technique that focuses on hyperbolic conservation laws and includes one-dimensional and two-dimensional shallow water flows and pollutant transports. Combines the Advantages of Finite Volume and Finite Element Methods This book explores the discontinuous Galerkin (DG) method, also known as the discontinuous finite element method, in depth. It introduces the DG method and its application to shallow water flows, as well as background information for implementing and applying this method for natural rivers. It considers dam-break problems, shock wave problems, and flows in different regimes (subcritical, supercritical, and transcritical). Readily Adaptable to the Real World While the DG method has been widely used in the fields of science and engineering, its use for hydraulics has so far been limited to simple cases. The book compares numerical results with laboratory experiments and field data, and includes a set of tests that can be used for a wide range of applications. Provides step-by-step implementation details Presents the different forms in which the shallow water flow equations can be written Places emphasis on the details and modifications required to apply the scheme to real-world flow problems This text enables readers to readily understand and develop an efficient computer simulation model that can be used to model flow, contaminant transport, and other aspects in rivers and coastal environments. It is an ideal resource for practicing environmental engineers and researchers in the area of computational hydraulics and fluid dynamics, and graduate students in computational hydraulics. Abstract: We first give a stabilized improved moving least squares (IMLS) approximation, which has better computational stability and precision than the IMLS approximation. Then, analysis of the improved element-free Galerkin method is provided theoretically for both linear and nonlinear elliptic boundary value problems. Finally, numerical examples are given to verify the theoretical analysis. Understand How to Use and Develop Meshfree Techniques An Update of a Groundbreaking Work Reflecting the significant advances made in the field since the publication of its predecessor, Meshfree Methods: Moving Beyond the Finite Element Method, Second Edition systematically covers the most widely used meshfree methods. With 70% new material, this edition addresses important new developments, especially on essential theoretical issues. New to the Second Edition Much more details on fundamental concepts and important theories for numerical methods Discussions on special properties of meshfree methods, including stability, convergence, accurate, efficiency, and bound property More detailed discussion on error estimation and adaptive analysis using meshfree methods Developments on combined meshfree/finite element method (FEM) models Comparison studies using meshfree and FEM Drawing on the author's own research, this book provides a single-source guide to meshfree techniques and theories that can effectively handle a variety of complex engineering problems. It analyzes how the methods work, explains how to use and develop the methods, and explores the problems associated with meshfree methods. To access MFree2D (copyright, G. R. Liu), which accompanies MESHFREE METHODS: MOVING BEYOND THE FINITE ELEMENT METHOD, Second Edition (978-1-4200-8209-8) by Dr. G. R. Liu, please go to the website: www.ase.uc.edu/~liugr An access code is needed to use program – to receive it please email Dr. Liu directly at: liugr@ucmail.uc.edu Dr. Liu will reply to you directly with the code, and you can then proceed to use the software. Meshfree Particle Methods is a comprehensive and systematic exposition of particle methods, meshfree Galerkin and partitition of unity methods, molecular dynamics methods, and multiscale methods. Most theories, computational formulations, and simulation results presented are recent developments in meshfree methods. They were either just published recently or even have not been published yet, many of them resulting from the authors ? own research. The presentation of the technical content is heuristic and explanatory with a balance between mathematical rigor and engineering practice. It can be used as a graduate textbook or a comprehensive source for researchers, providing the state of the art on Meshfree Particle Methods. The numerical treatment of partial differential equations with particle methods and meshfree discretization techniques is a very active research field both in the mathematics and engineering community. Due to their independence of a mesh, particle schemes and meshfree methods can deal with large geometric changes of the domain more easily than classical discretization techniques. Furthermore, meshfree methods offer a promising approach for the coupling of particle models to continuous models. This volume of LNCSE is a collection of the proceedings papers of the Fourth International Workshop on Meshfree Methods held in September 2007 in Bonn. The articles address the different meshfree methods (SPH, PUM, GFEM, EFGM, RKPM, etc.) and their application in applied mathematics, physics and engineering. The volume is intended to foster this very active and exciting area of interdisciplinary research and to present recent advances and results in this field. A variety of meshless methods have been developed in the last fifteen years with an intention to solve practical engineering problems, but are limited to small academic problems due to associated high computational cost as compared to the standard finite element methods (FEM). The main objective of this thesis is the development of an efficient and accurate algorithm based on meshless methods for the solution of problems involving both material and geometrical nonlinearities, which are of practical importance in many engineering applications, including geomechanics, metal forming and biomechanics. One of the most commonly used meshless methods, the element-free Galerkin method (EFGM) is used in this research, in which maximum entropy shape functions (max-ent) are used instead of the standard moving least squares shape functions, which provides direct imposition of the essential boundary conditions. Initially, theoretical background and corresponding computer implementations of the EFGM are described for linear and nonlinear problems. The Prandtl-Reuss constitutive model is used to model elasto-plasticity, both updated and total Lagrangian formulations are used to model finite deformation and consistent or algorithmic tangent is used to allow the quadratic rate of asymptotic convergence of the global Newton-Raphson algorithm. An adaptive strategy is developed for the EFGM for two- and three-dimensional nonlinear problems based on the Chung \& Belytschko error estimation procedure, which was originally proposed for linear elastic problems. A new FE-EFGM coupling procedure based on max-ent shape functions is proposed for linear and geometrically nonlinear problems, in which there is no need of interface elements between the FE and EFG regions or any other special treatment, as required in the most previous research. The proposed coupling procedure is extended to become adaptive FE-EFGM coupling for two- and three-dimensional linear and nonlinear problems, in which the Zienkiewicz \& Zhu error estimation procedure with the superconvergent patch recovery method for strains and stresses recovery are used in the FE region of the problem domain, while the Chung \& Belytschko error estimation procedure is used in the EFG region of the problem domain. Parallel computer algorithms based on distributed memory parallel computer architecture are also developed for different numerical techniques proposed in this thesis. In the parallel program, the message passing interface library is used for inter-processor communication and open-source software packages, METIS and MUMPS are used for the automatic domain decomposition and solution of the final system of linear equations respectively. Separate numerical examples are presented for each algorithm to demonstrate its correct implementation and performance, and results are compared with the corresponding analytical or reference results. This book is revised and expanded version of the original German text. The arrangement of the material and the structure are essentially unchanged. All remarks in the Preface to the German Edition regarding naming conventions for formulas, theorems, lemmas, and definitions are still valid as are those concerning the arrangement and choice of material. This book offers an introduction to the key ideas, basic analysis, and efficient implementation of discontinuous Galerkin finite element methods (DG-FEM) for the solution of partial differential equations. It covers all key theoretical results, including an overview of relevant results from approximation theory, convergence theory for numerical PDE's, and orthogonal polynomials. Through embedded Matlab codes, coverage discusses and implements the algorithms for a number of classic systems of PDE's: Maxwell's equations, Euler equations, incompressible Navier-Stokes equations, and Poisson- and Helmholtz equations. This paper presents improvements made to enhance the Element-Free Galerkin method (EFG) for NDE applications. By using orthogonal basis functions instead of the conventional polynomial basis, the inversion of the ill-conditioned shape function matrix is eliminated. Therefore, the accuracy of the results is improved. Preliminary one-dimensional (1-D) and two-dimensional (2-D) examples are presented to demonstrate the improvement in accuracy and efficiency offered by orthogonal basis functions. The subject of the book is the mathematical theory of the discontinuous Galerkin method (DGM), which is a relatively new technique for the numerical solution of partial differential equations. The book is concerned with the DGM developed for elliptic and parabolic equations and its applications to the numerical simulation of compressible flow. It deals with the theoretical as well as practical aspects of the DGM and treats the basic concepts and ideas of the DGM, as well as the latest significant findings and achievements in this area. The main benefit for readers and the book's uniqueness lie in the fact that it is sufficiently detailed, extensive and mathematically precise, while at the same time providing a comprehensible guide through a wide spectrum of discontinuous Galerkin techniques and a survey of the latest efficient, accurate and robust discontinuous Galerkin schemes for the solution of compressible flow. Focuses on three primal DG methods, covering both theory and computation, and providing the basic tools for analysis. As we attempt to solve engineering problems of ever increasing complexity, so must we develop and learn new methods for doing so. The Finite Difference Method used for centuries eventually gave way to Finite Element Methods (FEM), which better met the demands for flexibility, effectiveness, and accuracy in problems involving complex geometry. Now, Abstract: In this paper, based on the conjugate of the complex basis function, a new complex variable moving least-squares approximation is discussed. Then using the new approximation to obtain the shape function, an improved complex variable element-free Galerkin (ICVEFG) method is presented for two-dimensional (2D) elastoplasticity problems. Compared with the previous complex variable moving least-squares approximation, the new approximation has greater computational precision and efficiency. Using the penalty method to apply the essential boundary conditions, and using the constrained Galerkin weak form of 2D elastoplasticity to obtain the system equations, we obtain the corresponding formulae of the ICVEFG method for 2D elastoplasticity. Three selected numerical examples are presented using the ICVEFG method to show that the ICVEFG method has the advantages such as greater precision and computational efficiency over the conventional meshless methods.

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