NAIL A. GUMEROV and
RAMANI DURAISWAMI

FAST MULTIPOLE METHODS FOR THE HELMHOLTZ EQUATION IN THREE DIMENSIONS

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Léo Pomar

Fast Multipole Methods For The Helmholtz Equation In Three Dimensions:

   Fast Multipole Methods for the Helmholtz Equation in Three Dimensions Nail A Gumerov,Ramani Duraiswami,2005-01-27 This volume in the Elsevier Series in Electromagnetism presents a detailed in depth and self contained treatment of the Fast Multipole Method and its applications to the solution of the Helmholtz equation in three dimensions The Fast Multipole Method was pioneered by Rokhlin and Greengard in 1987 and has enjoyed a dramatic development and recognition during the past two decades This method has been described as one of the best 10 algorithms of the 20th century Thus it is becoming increasingly important to give a detailed exposition of the Fast Multipole Method that will be accessible to a broad audience of researchers This is exactly what the authors of this book have accomplished For this reason it will be a valuable reference for a broad audience of engineers physicists and applied mathematicians The Only book that provides comprehensive coverage of this topic in one location Presents a review of the basic theory of expansions of the Helmholtz equation solutions Comprehensive description of both mathematical and practical aspects of the fast multipole method and it s applications to issues described by the Helmholtz equation   *Excursions in Harmonic Analysis, Volume 3* Radu Balan,Matthew J. Begué,John J. Benedetto,Wojciech Czaja,Kasso A. Okoudjou,2015-06-02 This volume consists of contributions spanning a wide spectrum of harmonic analysis and its applications written by speakers at the February Fourier Talks from 2002 2013 Containing cutting edge results by an impressive array of mathematicians engineers and scientists in academia industry and government it will be an excellent reference for graduate students researchers and professionals in pure and applied mathematics physics and engineering Topics covered include spectral analysis and correlation radar and communications design theory and applications sparsity special topics in harmonic analysis The February Fourier Talks are held annually at the Norbert Wiener Center for Harmonic Analysis and Applications Located at the University of Maryland College Park the Norbert Wiener Center provides a state of the art research venue for the broad emerging area of mathematical engineering   The Nystrom Method in Electromagnetics Mei Song Tong,Weng Cho Chew,2020-08-10 A comprehensive step by step reference to the Nystr m Method for solving Electromagnetic problems using integral equations Computational electromagnetics studies the numerical methods or techniques that solve electromagnetic problems by computer programming Currently there are mainly three numerical methods for electromagnetic problems the finite difference time domain FDTD finite element method FEM and integral equation methods IEMs In the IEMs the method of moments MoM is the most widely used method but much attention is being paid to the Nystr m method as another IEM because it possesses some unique merits which the MoM lacks This book focuses on that method providing information on everything that students and professionals working in the field need to know Written by the top researchers in electromagnetics this complete reference book is a consolidation of advances made in the use of the Nystr m method for solving electromagnetic integral equations It begins by introducing the fundamentals of the electromagnetic theory and

computational electromagnetics before proceeding to illustrate the advantages unique to the Nystr m method through rigorous worked out examples and equations Key topics include quadrature rules singularity treatment techniques applications to conducting and penetrable media multiphysics electromagnetic problems time domain integral equations inverse scattering problems and incorporation with multilevel fast multiple algorithm Systematically introduces the fundamental principles equations and advantages of the Nystr m method for solving electromagnetic problems Features the unique benefits of using the Nystr m method through numerical comparisons with other numerical and analytical methods Covers a broad range of application examples that will point the way for future research The Nystrom Method in Electromagnetics is ideal for graduate students senior undergraduates and researchers studying engineering electromagnetics computational methods and applied mathematics Practicing engineers and other industry professionals working in engineering electromagnetics and engineering mathematics will also find it to be incredibly helpful

Mathematical Insights into Advanced Computer Graphics Techniques Yoshinori Dobashi,Shizuo Kaji,Kei Iwasaki,2018-11-27 This book presents cutting edge developments in the advanced mathematical theories utilized in computer graphics research fluid simulation realistic image synthesis and texture visualization and digital fabrication A spin off book from the International Symposium on Mathematical Progress in Expressive Image Synthesis in 2016 and 2017 MEIS2016 2017 held in Fukuoka Japan it includes lecture notes and an expert introduction to the latest research presented at the symposium The book offers an overview of the emerging interdisciplinary themes between computer graphics and driven mathematic theories such as discrete differential geometry Further it highlights open problems in those themes making it a valuable resource not only for researchers but also for graduate students interested in computer graphics and mathematics   IUTAM Symposium on the Vibration Analysis of Structures with Uncertainties Alexander K. Belyaev,Robin S. Langley,2010-12-02 The Symposium was aimed at the theoretical and numerical problems involved in modelling the dynamic response of structures which have uncertain properties due to variability in the manufacturing and assembly process with automotive and aerospace structures forming prime examples It is well known that the difficulty in predicting the response statistics of such structures is immense due to the complexity of the structure the large number of variables which might be uncertain and the inevitable lack of data regarding the statistical distribution of these variables The Symposium participants presented the latest thinking in this very active research area and novel techniques were presented covering the full frequency spectrum of low mid and high frequency vibration problems It was demonstrated that for high frequency vibrations the response statistics can saturate and become independent of the detailed distribution of the uncertain system parameters A number of presentations exploited this physical behaviour by using and extending methods originally developed in both phenomenological thermodynamics and in the fields of quantum mechanics and random matrix theory For low frequency vibrations a number of presentations focussed on parametric uncertainty modelling for example

probabilistic models interval analysis and fuzzy descriptions and on methods of propagating this uncertainty through a large dynamic model in an effi cient way At mid frequencies the problem is mixed and various hybrid schemes were proposed It is clear that a comprehensivesolution to the problem of predicting the vibration response of uncertain structures across the whole frequency range requires expertise across a wide range of areas including probabilistic and non probabilistic methods interval and info gap analysis statistical energy analysis statistical thermodynamics random wave approaches and large scale computations and this IUTAM symposium presented a unique opportunity to bring together outstanding international experts in these fields **Boundary Element Analysis** Martin Schanz,Olaf Steinbach,2007-04-29 This volume contains eleven contributions on boundary integral equation and boundary element methods Beside some historical and more analytical aspects in the formulation and analysis of boundary integral equations modern fast boundary element methods are also described and analyzed from a mathematical point of view In addition the book presents engineering and industrial applications that show the ability of boundary element methods to solve challenging problems from different fields

Numerical Recipes 3rd Edition William H. Press,2007-09-06 Do you want easy access to the latest methods in scientific computing This greatly expanded third edition of Numerical Recipes has it with wider coverage than ever before many new expanded and updated sections and two completely new chapters The executable C code now printed in colour for easy reading adopts an object oriented style particularly suited to scientific applications Co authored by four leading scientists from academia and industry Numerical Recipes starts with basic mathematics and computer science and proceeds to complete working routines The whole book is presented in the informal easy to read style that made earlier editions so popular Highlights of the new material include a new chapter on classification and inference Gaussian mixture models HMMs hierarchical clustering and SVMs a new chapter on computational geometry covering KD trees quad and octrees Delaunay triangulation and algorithms for lines polygons triangles and spheres interior point methods for linear programming MCMC an expanded treatment of ODEs with completely new routines and many new statistical distributions For support or to subscribe to an online version please visit www nr com Academic Press Library in Signal Processing ,2013-09-14 This fourth volume edited and authored by world leading experts gives a review of the principles methods and techniques of important and emerging research topics and technologies in Image Video Processing and Analysis Hardware Audio Acoustic and Speech Processing With this reference source you will Quickly grasp a new area of research Understand the underlying principles of a topic and its application Ascertain how a topic relates to other areas and learn of the research issues yet to be resolved Quick tutorial reviews of important and emerging topics of research in Image Video Processing and Analysis Hardware Audio Acoustic and Speech Processing Presents core principles and shows their application Reference content on core principles technologies algorithms and applications Comprehensive references to journal articles and other literature on which to build further more specific and detailed knowledge Edited by leading people in the field who through their

reputation have been able to commission experts to write on a particular topic **Parallel Computational Technologies** Leonid Sokolinsky,Mikhail Zymbler,2019-08-01 This book constitutes the refereed proceedings of the 13th International Conference on Parallel Computational Technologies PCT 2019 held in Kaliningrad Russia in April 2019 The 24 revised full papers presented were carefully reviewed and selected from 96 submissions The papers are organized in topical sections on high performance architectures tools and technologies parallel numerical algorithms supercomputer simulation *Analytic Methods of Sound Field Synthesis* Jens Ahrens,2012-01-26 This book puts the focus on serving human listeners in the sound field synthesis although the approach can be also exploited in other applications such as underwater acoustics or ultrasonics The author derives a fundamental formulation based on standard integral equations and the single layer potential approach is identified as a useful tool in order to derive a general solution He also proposes extensions to the single layer potential approach which allow for a derivation of explicit solutions for circular planar and linear distributions of secondary sources Based on above described formulation it is shown that the two established analytical approaches of Wave Field Synthesis and Near field Compensated Higher Order Ambisonics constitute specific solutions to the general problem which are covered by the single layer potential solution and its extensions *Handbook of Signal Processing Systems* Shuvra S. Bhattacharyya,Ed F. Deprettere,Rainer Leupers,Jarmo Takala,2010-09-10 It gives me immense pleasure to introduce this timely handbook to the research velopment communities in the eld of signal processing systems SPS This is the rst of its kind and represents state of the arts coverage of research in this eld The driving force behind information technologies IT hinges critically upon the major advances in both component integration and system integration The major breakthrough for the former is undoubtedly the invention of IC in the 50 s by Jack S Kilby the Nobel Prize Laureate in Physics 2000 In an integrated circuit all components were made of the same semiconductor material Beginning with the pocket calculator in 1964 there have been many increasingly complex applications followed In fact processing gates and memory storage on a chip have since then grown at an exponential rate following Moore s Law Moore himself admitted that Moore s Law had turned out to be more accurate longer lasting and deeper in impact than he ever imagined With greater device integration various signal processing systems have been realized for many killer IT applications Further breakthroughs in computer sciences and Internet technologies have also catalyzed large scale system integration All these have led to today s IT revolution which has profound impacts on our lifestyle and overall prospect of humanity It is hard to imagine life today without mobiles or Internets The success of SPS requires a well concerted integrated approach from mul ple disciplines such as device design and application *Unified Transform for Boundary Value Problems* Athanasios S. Fokas,Beatrice Pelloni,2015-01-01 This book describes state of the art advances and applications of the unified transform and its relation to the boundary element method The authors present the solution of boundary value problems from several different perspectives in particular the type of problems modeled by partial differential equations PDEs They discuss recent applications of the unified transform to

the analysis and numerical modeling of boundary value problems for linear and integrable nonlinear PDEs and the closely related boundary element method a well established numerical approach for solving linear elliptic PDEs The text is divided into three parts Part I contains new theoretical results on linear and nonlinear evolutionary and elliptic problems New explicit solution representations for several classes of boundary value problems are constructed and rigorously analyzed Part II is a detailed overview of variational formulations for elliptic problems It places the unified transform approach in a classic context alongside the boundary element method and stresses its novelty Part III presents recent numerical applications based on the boundary element method and on the unified transform **Advances In Underwater Acoustics, Structural Acoustics, And Computational Methodologies (In 4 Volumes)** Sean F Wu,Steffen Marburg,2025-04-29 This set of volumes encompasses the study of acoustics to diverse environments ranging from underwater and marine environments to structural and civil engineering computational models and aerospace engineering Each volume comprises peer reviewed publications in the related field of acoustics from the past decade arranged such as to review the existing literature examine new methodologies and then explore novel applications of pioneering acoustic principles With contributions by eminent acoustics researchers this set holds key insights for fellow acoustics researchers and engineers of any field impacted by acoustic phenomena Volume 1 s review chapters summarise theories like geoacoustic inversion as well as criticism of the Biot theory of propagation in fluid saturated porous solids while the new methodologies shown range from an efficient and stable coupled mode solution to a cell based smoothed radial point interpolation method The book concludes with promising applications like experimental evidence of horizontal refraction and bottom attenuation coefficient inversion Volume 2 reviews topics including radiation boundary conditions for the Helmholtz equation and analytical interpretation of the early literature on the theory of vibrations The methodologies range from coupled boundary element and energy flow method as well as sound radiation of a line source The work concludes with promising applications like Lamb Waves in a poroelastic plate and experimental validations of reconstructed excitation forces acting inside a solid enclosure Volume 3 provides summaries of theories including the benchmark study on eigenfrequencies of fluid loaded structures and the Burton and Miller method while the new methodologies presented range from a coupled boundary element and energy flow method to an efficient approach to the simulation of acoustic radiation The volume concludes with promising applications like a comparison of transient infinite elements and transient Kirchhoff integral methods as well as a fast multi frequency iterative acoustic boundary element method Volume 4 depicts the context of conventional methodologies including short wave components and Galbrun s equation while its new methodologies range from radiation and outflow boundary conditions for direct computation of acoustic and flow disturbances to the effect of airfoil shape on trailing edge noise The collection concludes with promising applications like helicopter noise predictions and conservative source interpolation methods for aeroacoustics An Invitation to Metamaterials Didier Felbacq,2025-04-03 This book provides a thorough introduction to

the fundamental principles and cutting edge applications of metamaterials It offers a balanced perspective combining theoretical experimental and computational approaches Topics covered include rapidly evolving areas such as metasurfaces quantum metamaterials and nonlinear metamaterials The book also extends its scope beyond optics to explore applications in acoustics thermal science mechanics and even seismology A dedicated chapter discusses topological insulators providing detailed insights into this advanced topic The text is designed for advanced graduate students and early career researchers in the field of metamaterials Specialists in the field will also benefit from the book s presentation of new developments and innovative approaches Two chapters focus on advanced mathematical methods including fiber bundles Chern numbers pseudodifferential operators and scattering theory These sections are crafted to be reasonably self contained with references provided for readers who wish to explore these topics further *Fast Multipole Boundary Element Method* Yijun Liu,2009-08-24 First book on the fast multipole BEM bringing together classical theory in BEM formulations and the fast multipole method **Computational Simulation in Architectural and Environmental Acoustics** Tetsuya Sakuma,Shinichi Sakamoto,Toru Otsuru,2014-08-05 This book reviews a variety of methods for wave based acoustic simulation and recent applications to architectural and environmental acoustic problems Following an introduction providing an overview of computational simulation of sound environment the book is in two parts four chapters on methods and four chapters on applications The first part explains the fundamentals and advanced techniques for three popular methods namely the finite difference time domain method the finite element method and the boundary element method as well as alternative time domain methods The second part demonstrates various applications to room acoustics simulation noise propagation simulation acoustic property simulation for building components and auralization This book is a valuable reference that covers the state of the art in computational simulation for architectural and environmental acoustics *Direct and Inverse Problems in Wave Propagation and Applications* Ivan Graham,Ulrich Langer,Jens Melenk,Mourad Sini,2013-10-14 This book is the third volume of three volume series recording the Radon Special Semester 2011 on Multiscale Simulation Analysis in Energy and the Environment taking place in Linz Austria October 3 7 2011 This book surveys recent developments in the analysis of wave propagation problems The topics covered include aspects of the forward problem and problems in inverse problems as well as applications in the earth sciences Wave propagation problems are ubiquitous in environmental applications such as seismic analysis acoustic and electromagnetic scattering The design of efficient numerical methods for the forward problem in which the scattered field is computed from known geometric configurations is very challenging due to the multiscale nature of the problems Even more challenging are inverse problems where material parameters and configurations have to be determined from measurements in conjunction with the forward problem This book contains review articles covering several state of the art numerical methods for both forward and inverse problems This collection of survey articles focusses on the efficient computation of wave propagation and scattering is a core problem in numerical mathematics

which is currently of great research interest and is central to many applications in energy and the environment Two generic applications which resonate strongly with the central aims of the Radon Special Semester 2011 are forward wave propagation in heterogeneous media and seismic inversion for subsurface imaging As an example of the first application modelling of absorption and scattering of radiation by clouds aerosol and precipitation is used as a tool for interpretation of e g solar infrared and radar measurements and as a component in larger weather climate prediction models in numerical weather forecasting As an example of the second application inverse problems in wave propagation in heterogeneous media arise in the problem of imaging the subsurface below land or marine deposits The book records the achievements of Workshop 3 Wave Propagation and Scattering Inverse Problems and Applications in Energy and the Environment It brings together key numerical mathematicians whose interest is in the analysis and computation of wave propagation and scattering problems and in inverse problems together with practitioners from engineering and industry whose interest is in the applications of these core problems   Theory and Applications of Spherical Microphone Array Processing Daniel P. Jarrett,Emanuël A.P. Habets,Patrick A. Naylor,2016-08-26 This book presents the signal processing algorithms that have been developed to process the signals acquired by a spherical microphone array Spherical microphone arrays can be used to capture the sound field in three dimensions and have received significant interest from researchers and audio engineers Algorithms for spherical array processing are different to corresponding algorithms already known in the literature of linear and planar arrays because the spherical geometry can be exploited to great beneficial effect The authors aim to advance the field of spherical array processing by helping those new to the field to study it efficiently and from a single source as well as by offering a way for more experienced researchers and engineers to consolidate their understanding adding either or both of breadth and depth The level of the presentation corresponds to graduate studies at MSc and PhD level This book begins with a presentation of some of the essential mathematical and physical theory relevant to spherical microphone arrays and of an acoustic impulse response simulation method which can be used to comprehensively evaluate spherical array processing algorithms in reverberant environments The chapter on acoustic parameter estimation describes the way in which useful descriptions of acoustic scenes can be parameterized and the signal processing algorithms that can be used to estimate the parameter values using spherical microphone arrays Subsequent chapters exploit these parameters including in particular measures of direction of arrival and of diffuseness of a sound field The array processing algorithms are then classified into two main classes each described in a separate chapter These are signal dependent and signal independent beamforming algorithms Although signal dependent beamforming algorithms are in theory able to provide better performance compared to the signal independent algorithms they are currently rarely used in practice The main reason for this is that the statistical information required by these algorithms is difficult to estimate In a subsequent chapter it is shown how the estimated acoustic parameters can be used in the design of signal dependent beamforming algorithms This final step closes at least in

part the gap between theory and practice   **High performance computing for solving large sparse systems. Optical diffraction tomography as a case of study** Gloria Ortega López,2015-04-14 This thesis entitled High Performance Computing for solving large sparse systems Optical Diffraction Tomography as a case of study investigates the computational issues related to the resolution of linear systems of equations which come from the discretization of physical models described by means of Partial Differential Equations PDEs These physical models are conceived for the description of the space temporary behavior of some physical phenomena f x y z t in terms of their variations partial derivative with respect to the dependent variables of the phenomena There is a wide variety of discretization methods for PDEs Two of the most well known methods are the Finite Difference Method FDM and the Finite Element Method FEM Both methods result in an algebraic description of the model that can be translated into the approach of a linear system of equations of type Ax b where A is a sparse matrix a high percentage of zero elements whose size depends on the required accuracy of the modeled phenomena This thesis begins with the algebraic description of the model associated with the physical phenomena and the work herein has been focused on the design of techniques and computational models that allow the resolution of these linear systems of equations The main interest of this study is specially focused on models which require a high level of discretization and usually generate sparse matrices A which have a highly sparse structure and large size Literature characterizes these types of problems by their high demanding computational requirements because of their fine degree of discretization and the sparsity of the matrices involved suggesting that these kinds of problems can only be solved using High Performance Computing techniques and architectures One of the main goals of this thesis is the research of the possible alternatives which allow the implementation of routines to solve large and sparse linear systems of equations using High Performance Computing HPC The use of massively parallel platforms GPUs allows the acceleration of these routines because they have several advantages for vectorial computation schemes On the other hand the use of distributed memory platforms allows the resolution of problems defined by matrices of enormous size Finally the combination of both techniques distributed computation and multi GPUs will allow faster resolution of interesting problems in which large and sparse matrices are involved In this line one of the goals of this thesis is to supply the scientific community with implementations based on multi GPU clusters to solve sparse linear systems of equations which are the key in many scientific computations The second part of this thesis is focused on a real physical problem of Optical Diffractional Tomography ODT based on holographic information ODT is a non damaging technique which allows the extraction of the shapes of objects with high accuracy Therefore this technique is very suitable to the in vivo study of real specimens microorganisms etc and it also makes the investigation of their dynamics possible A preliminary physical model based on a bidimensional reconstruction of the seeding particle distribution in fluids was proposed by J Lobera and J M Coupland However its high computational cost in both memory requirements and runtime made compulsory the use of HPC techniques to extend the implementation to a three

dimensional model In the second part of this thesis the implementation and validation of this physical model for the case of three dimensional reconstructions is carried out In such implementation the resolution of large and sparse linear systems of equations is required Thus some of the algebraic routines developed in the first part of the thesis have been used to implement computational strategies capable of solving the problem of 3D reconstruction based on ODT   Computational Acoustics of Noise Propagation in Fluids - Finite and Boundary Element Methods Steffen Marburg,Bodo Nolte,2008-02-27 The book provides a survey of numerical methods for acoustics namely the finite element method FEM and the boundary element method BEM It is the first book summarizing FEM and BEM and optimization for acoustics The book shows that both methods can be effectively used for many other cases FEM even for open domains and BEM for closed ones Emphasis of the book is put on numerical aspects and on treatment of the exterior problem in acoustics i e noise radiation

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