Finite-element methods for Electromagnetics
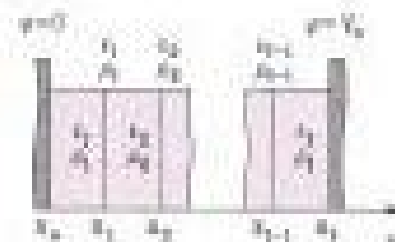
Stanley Humphries

Field Precision LLC

Figure 4.7: [illegible caption] one-dimensional gap-index convention for finite-difference and finite-element treatments.

$$[\text{illegible equations}] \tag{4.42}$$

Powerful tools for the solution of ordinary differential equations can be created by combining high-order integration schemes with routines to optimize (s) continuously. Methods to implement adaptive step size are described in W. H. Press, S. A. Teukolsky, W. T. Vetterling and B. P. Flannery, **Numerical Recipes in Fortran**, Second Edition (Cambridge University Press, Cambridge, 1992), Chapter 16.

4.3 One-dimensional Poisson equation

This section reviews difference equations for the one-dimensional Poisson equation.

$$\frac{\partial}{\partial x}\left(\epsilon\,\frac{\partial\phi}{\partial x}\right) = -\frac{\rho}{\epsilon_0} \tag{4.43}$$

We shall compare finite-difference and finite-element viewpoints using the index convention of Figure 4.7. To begin, we shall find a discrete form for Equation 4.43 using difference operators applied at points. Suppose that ϵ and ρ are continuous functions in space and have the following set of values at mesh positions:

$$\epsilon_i = \epsilon_i(x_i), \quad \rho_i = \rho_i(x_i). \tag{4.44}$$

An approximation for the left-hand side of Equation 4.43 at position x_i follows from the difference between centered estimates of $\epsilon\,\partial\phi/\partial x$ in adjacent intervals divided by $(x_{i+1} - x_i)/2$. The expression to the left of point x_i is

$$\epsilon\,\frac{\partial\phi}{\partial x} \cong \epsilon_{i-1/2}\,\frac{\phi_i - \phi_{i-1}}{x_i - x_{i-1}} \tag{4.45}$$

Finite Element Method In Electromagnetics

Jian-Ming Jin

Finite Element Method In Electromagnetics:

Introduction to the Finite Element Method in Electromagnetics Anastasis C. Polycarpou,2006-12-01 This series lecture is an introduction to the finite element method with applications in electromagnetics The finite element method is a numerical method that is used to solve boundary value problems characterized by a partial differential equation and a set of boundary conditions The geometrical domain of a boundary value problem is discretized using sub domain elements called the finite elements and the differential equation is applied to a single element after it is brought to a weak integro differential form A set of shape functions is used to represent the primary unknown variable in the element domain A set of linear equations is obtained for each element in the discretized domain A global matrix system is formed after the assembly of all elements This lecture is divided into two chapters Chapter 1 describes one dimensional boundary value problems with applications to electrostatic problems described by the Poisson s equation The accuracy of the finite element method is evaluated for linear and higher order elements by computing the numerical error based on two different definitions Chapter 2 describes two dimensional boundary value problems in the areas of electrostatics and electrodynamics time harmonic problems For the second category an absorbing boundary condition was imposed at the exterior boundary to simulate undisturbed wave propagation toward infinity Computations of the numerical error were performed in order to evaluate the accuracy and effectiveness of the method in solving electromagnetic problems Both chapters are accompanied by a number of Matlab codes which can be used by the reader to solve one and two dimensional boundary value problems These codes can be downloaded from the publisher s URL www morganclaypool com page polycarpou This lecture is written primarily for the nonexpert engineer or the undergraduate or graduate student who wants to learn for the first time the finite element method with applications to electromagnetics It is also targeted for research engineers who have knowledge of other numerical techniques and want to familiarize themselves with the finite element method The lecture begins with the basics of the method including formulating a boundary value problem using a weighted residual method and the Galerkin approach and continues with imposing all three types of boundary conditions including absorbing boundary conditions Another important topic of emphasis is the development of shape functions including those of higher order In simple words this series lecture provides the reader with all information necessary for someone to apply successfully the finite element method to one and two dimensional boundary value problems in electromagnetics It is suitable for newcomers in the field of finite elements in electromagnetics   The Finite Element Method in Electromagnetics Jian-Ming Jin,2014-03-31 A new edition of the leading textbook on the finite element method incorporating major advancements and further applications in the field of electromagnetics The finite element method FEM is a powerful simulation technique used to solve boundary value problems in a variety of engineering circumstances It has been widely used for analysis of electromagnetic fields in antennas radar scattering RF and microwave engineering high speed high frequency circuits wireless communication electromagnetic

compatibility photonics remote sensing biomedical engineering and space exploration The Finite Element Method in Electromagnetics Third Edition explains the method s processes and techniques in careful meticulous prose and covers not only essential finite element method theory but also its latest developments and applications giving engineers a methodical way to quickly master this very powerful numerical technique for solving practical often complicated electromagnetic problems Featuring over thirty percent new material the third edition of this essential and comprehensive text now includes A wider range of applications including antennas phased arrays electric machines high frequency circuits and crystal photonics The finite element analysis of wave propagation scattering and radiation in periodic structures The time domain finite element method for analysis of wideband antennas and transient electromagnetic phenomena Novel domain decomposition techniques for parallel computation and efficient simulation of large scale problems such as phased array antennas and photonic crystals Along with a great many examples The Finite Element Method in Electromagnetics is an ideal book for engineering students as well as for professionals in the field **Frequency Domain Hybrid Finite Element Methods in Electromagnetics** John. L Volakis,Kubilay Sertel,Brian C Usner,2022-06-01 This book provides a brief overview of the popular Finite Element Method FEM and its hybrid versions for electromagnetics with applications to radar scattering antennas and arrays guided structures microwave components frequency selective surfaces periodic media and RF materials characterizations and related topics It starts by presenting concepts based on Hilbert and Sobolev spaces as well as Curl and Divergence spaces for generating matrices useful in all engineering simulation methods It then proceeds to present applications of the finite element and finite element boundary integral methods for scattering and radiation Applications to periodic media metamaterials and bandgap structures are also included The hybrid volume integral equation method for high contrast dielectrics and is presented for the first time Another unique feature of the book is the inclusion of design optimization techniques and their integration within commercial numerical analysis packages for shape and material design To aid the reader with the method s utility an entire chapter is devoted to two dimensional problems The book can be considered as an update on the latest developments since the publication of our earlier book Finite Element Method for Electromagnetics IEEE Press 1998 The latter is certainly complementary companion to this one **Finite Element Method Electromagnetics** John L. Volakis,Arindam Chatterjee,Leo C. Kempel,1998-06-15 Employed in a large number of commercial electromagnetic simulation packages the finite element method is one of the most popular and well established numerical techniques in engineering This book covers the theory development implementation and application of the finite element method and its hybrid versions to electromagnetics FINITE ELEMENT METHOD FOR ELECTROMAGNETICS begins with a step by step textbook presentation of the finite method and its variations then goes on to provide up to date coverage of three dimensional formulations and modern applications to open and closed domain problems Worked out examples are included to aid the reader with the fine features of the method and the implementation of its hybridization with other

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topics of research in field computation are explored in this publication Contributions have been sourced from international experts ensuring a comprehensive specialist perspective A unity of style has been achieved by the editor who has specifically inserted appropriate cross references throughout the volume plus a single collected set of references at the end The book provides a multi faceted overview of the power and effectiveness of computation techniques in engineering electromagnetics In addition to examining recent and current developments it is hoped that it will stimulate further research in the field

Iterative and Self-adaptive Finite-elements in Electromagnetic Modeling Magdalena Salazar-Palma,1998 Ensure the accuracy of your results when applying the Finite Element Method FEM to electromagnetic and antenna problems with this self contained reference It provides you with a solid understanding of the method describes its key elements and numerical techniques and identifies various approaches to using the FEM in solving real world microwave field problems

The Finite Element Method for Electromagnetic Modeling Gérard Meunier,2010-01-05 The Finite Element Method for Electromagnetic Modeling Written by specialists in the modeling of electromagnetism this book provides a comprehensive review of the finite element method for low frequency applications Fundamentals of the method as well as new advances in the field are described in detail Static magnetodynamic and fixed formulations are first covered before the discussion moves on to different macroscopic behavior laws of materials and their implementation in a finite element context and to more specific formulations the modeling of thin regions when finite elements become ill fitting the coupling of 2D and 3D formulations with circuit equations taking into account the presence of eddy currents and the treatment of geometric symmetries when the sources are not symmetric Coupled problems are then outlined before the book concludes with coverage of different meshing methods in the context of electromagnetism and optimization techniques *Finite Elements for Wave Electromagnetics* IEEE Antennas and Propagation Society,1994 **Finite Element Method in Electromagnetics Paper SEA** Jian-Ming Jin,1994-11-14 **The Finite Element Method in Electromagnetics** Jian-Ming Jin,2015-02-18 A new edition of the leading textbook on the finite element method incorporating major advancements and further applications in the field of electromagnetics The finite element method FEM is a powerful simulation technique used to solve boundary value problems in a variety of engineering circumstances It has been widely used for analysis of electromagnetic fields in antennas radar scattering RF and microwave engineering high speed high frequency circuits wireless communication electromagnetic compatibility photonics remote sensing biomedical engineering and space exploration The Finite Element Method in Electromagnetics Third Edition explains the method s processes and techniques in careful meticulous prose and covers not only essential finite element method theory but also its latest developments and applications giving engineers a methodical way to quickly master this very powerful numerical technique for solving practical often complicated electromagnetic problems Featuring over thirty percent new material the third edition of this essential and comprehensive text now includes A wider range of applications including antennas phased arrays electric machines high

frequency circuits and crystal photonics The finite element analysis of wave propagation scattering and radiation in periodic structures The time domain finite element method for analysis of wideband antennas and transient electromagnetic phenomena Novel domain decomposition techniques for parallel computation and efficient simulation of large scale problems such as phased array antennas and photonic crystals Along with a great many examples The Finite Element Method in Electromagnetics is an ideal book for engineering students as well as for professionals in the field   Finite Element Method for Eigenvalue Problems in Electromagnetics C. J. Reddy,1994   **Electromagnetics Through the Finite Element Method** Jos?e Roberto Cardoso,2017   **Multigrid Finite Element Methods for Electromagnetic Field Modeling** Yu Zhu,Andreas C. Cangellaris,2006-02-17 This is the first comprehensive monograph that features state of the art multigrid methods for enhancing the modeling versatility numerical robustness and computational efficiency of one of the most popular classes of numerical electromagnetic field modeling methods the method of finite elements The focus of the publication is the development of robust preconditioners for the iterative solution of electromagnetic field boundary value problems BVPs discretized by means of finite methods Specifically the authors set forth their own successful attempts to utilize concepts from multigrid and multilevel methods for the effective preconditioning of matrices resulting from the approximation of electromagnetic BVPs using finite methods Following the authors careful explanations and step by step instruction readers can duplicate the authors results and take advantage of today s state of the art multigrid multilevel preconditioners for finite element based iterative electromagnetic field solvers Among the highlights of coverage are Application of multigrid multilevel and hybrid multigrid multilevel preconditioners to electromagnetic scattering and radiation problems Broadband robust numerical modeling of passive microwave components and circuits Robust finite element based modal analysis of electromagnetic waveguides and cavities Application of Krylov subspace based methodologies for reduced order macromodeling of electromagnetic devices and systems Finite element modeling of electromagnetic waves in periodic structures The authors provide more than thirty detailed algorithms alongside pseudo codes to assist readers with practical computer implementation In addition each chapter includes an applications section with helpful numerical examples that validate the authors methodologies and demonstrate their computational efficiency and robustness This groundbreaking book with its coverage of an exciting new enabling computer aided design technology is an essential reference for computer programmers designers and engineers as well as graduate students in engineering and applied physics   **Finite Element Method to Model Electromagnetic Systems in Low Frequency** Francis Piriou,Stephane Clenet,2024-03-26 Numerical modeling now plays a central role in the design and study of electromagnetic systems In the field of devices operating in low frequency it is the finite element method that has come to the fore in recent decades Today it is widely used by engineers and researchers in industry as well as in research centers This book describes in detail all the steps required to discretize Maxwell s equations using the finite element method This involves progressing from the basic equations in the continuous

domain to equations in the discrete domain that are solved by a computer This approach is carried out with a constant focus on maintaining a link between physics i e the properties of electromagnetic fields and numerical analysis Numerous academic examples which are used throughout the various stages of model construction help to clarify the developments

Generalized Finite Element Method for Electromagnetic Analysis Chuan Lu,2008

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