

## Numerical Differential Protection Principles And Applications

The fundamental mathematical tools needed to understand machine learning include linear algebra, analytic geometry, matrix decompositions, vector calculus, optimization, probability and statistics. These topics are traditionally taught in disparate courses, making it hard for data science or computer science students, or professionals, to efficiently learn the mathematics. This self-contained textbook bridges the gap between mathematical and machine learning texts, introducing the mathematical concepts with a minimum of prerequisites. It uses these concepts to derive four central machine learning methods: linear regression, principal component analysis, Gaussian mixture models and support vector machines. For students and others with a mathematical background, these derivations provide a starting point to machine learning texts. For those learning the mathematics for the first time, the methods help build intuition and practical experience with applying mathematical concepts. Every chapter includes worked examples and exercises to test understanding. Programming tutorials are offered on the book's web site.

For readers with some competence in PDE solution properties, this book offers an interdisciplinary approach to problems occurring in natural environmental media: the hydrosphere, atmosphere, cryosphere, lithosphere, biosphere and ionosphere. It presents two major discretization methods: Finite Difference and Finite Element, plus a section on practical approaches to ill-posed problems. The blend of theory, analysis, and implementation practicality supports solving and understanding complicated problems.

This book is a practical guide to digital protective relays in power systems. It explains the theory of how the protective relays work in power systems, provides the engineering knowledge and tools to successfully design them and offers expert advice on how they behave in practical circumstances. This book helps readers gain technical mastery of how the relays function, how they are designed and how they perform. This text not only features in-depth coverage of the theory and principles behind protective relays, but also includes a manual supplemented with software that offers numerous hands-on examples in MATLAB. A great resource for protective relaying labs and self-learners, its manual provides lab experiments unavailable elsewhere. The book is suitable for advanced courses in Digital Relays and Power Systems Fault Analysis and Protection, and will prove to be a valuable resource for practitioners in the utility industry, including relay designers.

Revised and updated, this second edition of Walter Gautschi's successful Numerical Analysis explores computational methods for problems arising in the areas of classical analysis, approximation theory, and ordinary differential equations, among others. Topics included in the book are presented with a view toward stressing basic principles and maintaining simplicity and teachability as

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far as possible, while subjects requiring a higher level of technicality are referenced in detailed bibliographic notes at the end of each chapter. Readers are thus given the guidance and opportunity to pursue advanced modern topics in more depth. Along with updated references, new biographical notes, and enhanced notational clarity, this second edition includes the expansion of an already large collection of exercises and assignments, both the kind that deal with theoretical and practical aspects of the subject and those requiring machine computation and the use of mathematical software. Perhaps most notably, the edition also comes with a complete solutions manual, carefully developed and polished by the author, which will serve as an exceptionally valuable resource for instructors.

Electrical Power System Protection provides practising engineers with the most up-to-date and comprehensive one -volume reference and tutorial on power system protection available. Concentrating on fundamental methods and technology and with extensive examples drawn from current practice internationally, this book will be a major reference tool for engineers involved with and affected by power system protection.

The problem of privacy-preserving data analysis has a long history spanning multiple disciplines. As electronic data about individuals becomes increasingly detailed, and as technology enables ever more powerful collection and curation of these data, the need increases for a robust, meaningful, and mathematically rigorous definition of privacy, together with a computationally rich class of algorithms that satisfy this definition. Differential Privacy is such a definition. The Algorithmic Foundations of Differential Privacy starts out by motivating and discussing the meaning of differential privacy, and proceeds to explore the fundamental techniques for achieving differential privacy, and the application of these techniques in creative combinations, using the query-release problem as an ongoing example. A key point is that, by rethinking the computational goal, one can often obtain far better results than would be achieved by methodically replacing each step of a non-private computation with a differentially private implementation. Despite some powerful computational results, there are still fundamental limitations. Virtually all the algorithms discussed herein maintain differential privacy against adversaries of arbitrary computational power -- certain algorithms are computationally intensive, others are efficient. Computational complexity for the adversary and the algorithm are both discussed. The monograph then turns from fundamentals to applications other than query-release, discussing differentially private methods for mechanism design and machine learning. The vast majority of the literature on differentially private algorithms considers a single, static, database that is subject to many analyses. Differential privacy in other models, including distributed databases and computations on data streams, is discussed. The Algorithmic Foundations of Differential Privacy is meant as a thorough introduction to the problems and techniques of differential privacy, and is an invaluable reference for anyone with

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an interest in the topic.

When planning an industrial power supply plant, the specific requirements of the individual production process are decisive for the design and mode of operation of the network and for the selection and design and ratings of the operational equipment. Since the actual technical risks are often hidden in the profound and complex planning task, planning decisions should be taken after responsible and careful consideration because of their deep effects on supply quality and energy efficiency. This book is intended for engineers and technicians of the energy industry, industrial companies and planning departments. It provides basic technical network and plant knowledge on planning, installation and operation of reliable and economic industrial networks. In addition, it facilitates training for students and graduates in this field. In an easy and comprehensible way, this book informs about solution competency gained in many years of experience. Moreover, it also offers planning recommendations and knowledge on standards and specifications, the use of which ensures that technical risks are avoided and that production and industrial processes can be carried out efficiently, reliably and with the highest quality.

Distance protection provides the basis for network protection in transmission systems and meshed distribution systems. This book covers the fundamentals of distance protection and the special features of numerical technology. The emphasis is placed on the application of numerical distance relays in distribution and transmission systems. This book is aimed at students and engineers who wish to familiarise themselves with the subject of power system protection, as well as the experienced user, entering the area of numerical distance protection. Furthermore it serves as a reference guide for solving application problems. For this fourth edition all contents, especially the descriptions of numerical protection devices and the very useful appendix have been revised and updated.

For many years, Protective Relaying: Principles and Applications has been the go-to text for gaining proficiency in the technological fundamentals of power system protection. Continuing in the bestselling tradition of the previous editions by the late J. Lewis Blackburn, the Fourth Edition retains the core concepts at the heart of power system analysis. Featuring refinements and additions to accommodate recent technological progress, the text: Explores developments in the creation of smarter, more flexible protective systems based on advances in the computational power of digital devices and the capabilities of communication systems that can be applied within the power grid Examines the regulations related to power system protection and how they impact the way protective relaying systems are designed, applied, set, and monitored Considers the evaluation of protective systems during system disturbances and describes the tools available for analysis Addresses the benefits and problems associated with applying microprocessor-based devices in protection schemes Contains an expanded discussion of intertie protection requirements at dispersed generation facilities Providing information on a mixture of old and new equipment, Protective

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Relaying: Principles and Applications, Fourth Edition reflects the present state of power systems currently in operation, making it a handy reference for practicing protection engineers. And yet its challenging end-of-chapter problems, coverage of the basic mathematical requirements for fault analysis, and real-world examples ensure engineering students receive a practical, effective education on protective systems. Plus, with the inclusion of a solutions manual and figure slides with qualifying course adoption, the Fourth Edition is ready-made for classroom implementation.

The theme of HumanCom and EMC is focused on the various aspects of human-centric computing for advances in computer science and its applications, embedded and multimedia computing and provides an opportunity for academic and industry professionals to discuss the latest issues and progress in the area of human-centric computing. And the theme of EMC (Advanced in Embedded and Multimedia Computing) is focused on the various aspects of embedded system, smart grid, cloud and multimedia computing, and it provides an opportunity for academic, industry professionals to discuss the latest issues and progress in the area of embedded and multimedia computing. Therefore this book will be include the various theories and practical applications in human-centric computing and embedded and multimedia computing.

This up-to-date book gives an account of the present state of the art of numerical methods employed in computational fluid dynamics. The underlying numerical principles are treated in some detail, using elementary methods. The author gives many pointers to the current literature, facilitating further study. This book will become the standard reference for CFD for the next 20 years.

The essential introduction to the principles and applications of feedback systems—now fully revised and expanded This textbook covers the mathematics needed to model, analyze, and design feedback systems. Now more user-friendly than ever, this revised and expanded edition of Feedback Systems is a one-volume resource for students and researchers in mathematics and engineering. It has applications across a range of disciplines that utilize feedback in physical, biological, information, and economic systems. Karl Åström and Richard Murray use techniques from physics, computer science, and operations research to introduce control-oriented modeling. They begin with state space tools for analysis and design, including stability of solutions, Lyapunov functions, reachability, state feedback observability, and estimators. The matrix exponential plays a central role in the analysis of linear control systems, allowing a concise development of many of the key concepts for this class of models. Åström and Murray then develop and explain tools in the frequency domain, including transfer functions, Nyquist analysis, PID control, frequency domain design, and robustness. Features a new chapter on design principles and tools, illustrating the types of problems that can be solved using feedback Includes a new chapter on fundamental limits and new material on the Routh-Hurwitz criterion and root locus plots Provides exercises at the end of every chapter Comes with an

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electronic solutions manual An ideal textbook for undergraduate and graduate students Indispensable for researchers seeking a self-contained resource on control theory

Differential protection is a fast and selective method of protection against short-circuits. It is applied in many variants for electrical machines, transformers, busbars, and electric lines. Initially this book covers the theory and fundamentals of analog and numerical differential protection. Current transformers are treated in detail including transient behaviour, impact on protection performance, and practical dimensioning. An extended chapter is dedicated to signal transmission for line protection, in particular, modern digital communication and GPS timing. The emphasis is then placed on the different variants of differential protection and their practical application illustrated by concrete examples. This is completed by recommendations for commissioning, testing and maintenance. Finally the design and management of modern differential protection is explained by means of the latest Siemens SIPROTEC relay series. As a textbook and standard work in one, this book covers all topics, which have to be paid attention to for planning, designing, configuring and applying differential protection systems. The book is aimed at students and engineers who wish to familiarise themselves with the subject of differential protection, as well as the experienced user entering the area of numerical differential protection. Furthermore, it serves as a reference guide for solving application problems. For the new edition all contents have been revised, extended and updated to the latest state-of-the-art of protective relaying.

This book provides a comprehensive overview on the latest developments in the control, operation, and protection of microgrids. It provides readers with a solid approach to analyzing and understanding the salient features of modern control and operation management techniques applied to these systems, and presents practical methods with examples and case studies from actual and modeled microgrids. The book also discusses emerging concepts, key drivers and new players in microgrids, and local energy markets while addressing various aspects from day-ahead scheduling to real-time testing of microgrids. The book will be a valuable resource for researchers who are focused on control concepts, AC, DC, and AC/DC microgrids, as well as those working in the related areas of energy engineering, operations research and its applications to energy systems.

Presents modern operation, control and protection techniques with applications to real world and emulated microgrids; Discusses emerging concepts, key drivers and new players in microgrids and local energy markets; Addresses various aspects from day-ahead scheduling to real-time testing of microgrids.

Numerical Differential Protection Principles and Applications John Wiley & Sons

A systematic view of hierarchical protection for smart grids, with solutions to traditional protection problems and complicated operation modes of modern power systems •

Systematically investigates traditional protection problems from the bird's eye view of hierarchical protection • Focuses on multiple variable network structures and

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complicated operation modes • Offers comprehensive countermeasures on improving protection performance based on up-to-date research

At the intersection of mathematics, engineering, and computer science sits the thriving field of compressive sensing. Based on the premise that data acquisition and compression can be performed simultaneously, compressive sensing finds applications in imaging, signal processing, and many other domains. In the areas of applied mathematics, electrical engineering, and theoretical computer science, an explosion of research activity has already followed the theoretical results that highlighted the efficiency of the basic principles. The elegant ideas behind these principles are also of independent interest to pure mathematicians. A Mathematical Introduction to Compressive Sensing gives a detailed account of the core theory upon which the field is built. With only moderate prerequisites, it is an excellent textbook for graduate courses in mathematics, engineering, and computer science. It also serves as a reliable resource for practitioners and researchers in these disciplines who want to acquire a careful understanding of the subject. A Mathematical Introduction to Compressive Sensing uses a mathematical perspective to present the core of the theory underlying compressive sensing.

Gerhard Ziegler Numerical Distance Protection Distance protection provides the basis for network protection in transmission systems and meshed distribution systems. Initially this book covers the fundamentals of distance protection and the special features of numerical technology. The emphasis is then placed on the application of numerical distance relays in distribution and transmission systems. This book is aimed at students and engineers who wish to familiarise themselves with the subject of power system protection, as well as the experienced user, entering the area of numerical distance protection. Furthermore it serves as a reference guide for solving application problems. Contents General principles of distance protection Numerical distance measurement Influencing signals Device configuration Application in distribution and industrial networks Application in transmission networks Protection settings Calculation examples Commissioning, testing and maintenance of protection system

This volume provides an introduction to the analytical and numerical aspects of partial differential equations (PDEs). It unifies an analytical and computational approach for these; the qualitative behaviour of solutions being established using classical concepts: maximum principles and energy methods. Notable inclusions are the treatment of irregularly shaped boundaries, polar coordinates and the use of flux-limiters when approximating hyperbolic conservation laws. The numerical analysis of difference schemes is rigorously developed using discrete maximum principles and discrete Fourier analysis. A novel feature is the inclusion of a chapter containing projects, intended for either individual or group study, that cover a range of topics such as parabolic smoothing, travelling waves, isospectral matrices, and the approximation of multidimensional advection–diffusion problems. The underlying theory is illustrated by numerous examples and there are around 300 exercises, designed to promote and test understanding. They are starred according to level of difficulty. Solutions to odd-numbered exercises are available to all readers while even-numbered solutions are available to authorised instructors. Written in an informal yet rigorous style, Essential Partial Differential Equations is designed for mathematics undergraduates in their final or penultimate year of university study, but will be equally useful for students following

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other scientific and engineering disciplines in which PDEs are of practical importance. The only prerequisite is a familiarity with the basic concepts of calculus and linear algebra.

The main theme is the integration of the theory of linear PDE and the theory of finite difference and finite element methods. For each type of PDE, elliptic, parabolic, and hyperbolic, the text contains one chapter on the mathematical theory of the differential equation, followed by one chapter on finite difference methods and one on finite element methods. The chapters on elliptic equations are preceded by a chapter on the two-point boundary value problem for ordinary differential equations. Similarly, the chapters on time-dependent problems are preceded by a chapter on the initial-value problem for ordinary differential equations. There is also one chapter on the elliptic eigenvalue problem and eigenfunction expansion. The presentation does not presume a deep knowledge of mathematical and functional analysis. The required background on linear functional analysis and Sobolev spaces is reviewed in an appendix. The book is suitable for advanced undergraduate and beginning graduate students of applied mathematics and engineering.

This book is a long awaited comprehensive introduction to the protection of electrical power systems using computer-based methods (i.e. digital relays). The treatment is logically structured, taking the reader through the mathematics and principles underlying the development and implementation of the major algorithms underlying different protection techniques. They can be applied to protection of generator transformers, lines, switchgear and cable circuits: the main components of transmission and distribution systems. The book deals with the research and development activity in the field of digital protection during the last 15 years. The reader will become familiarised with the fast developing field of power system protection using computers and microcomputers. "This book provides a full introduction for senior undergraduates and graduates, and acts as a sound reference for engineers already practising in this area."

This book offers an ideal graduate-level introduction to the theory of partial differential equations. The first part of the book describes the basic mathematical problems and structures associated with elliptic, parabolic, and hyperbolic partial differential equations, and explores the connections between these fundamental types. Aspects of Brownian motion or pattern formation processes are also presented. The second part focuses on existence schemes and develops estimates for solutions of elliptic equations, such as Sobolev space theory, weak and strong solutions, Schauder estimates, and Moser iteration. In particular, the reader will learn the basic techniques underlying current research in elliptic partial differential equations. This revised and expanded third edition is enhanced with many additional examples that will help motivate the reader. New features include a reorganized and extended chapter on hyperbolic equations, as well as a new chapter on the relations between different types of partial differential equations, including first-order hyperbolic systems, Langevin and Fokker-Planck equations, viscosity solutions for elliptic PDEs, and much more. Also, the new edition contains additional material on systems of elliptic partial differential equations, and it explains in more detail how the Harnack inequality can be used for the regularity of solutions.

Arguably, many industrial optimization problems are of the multiobjective type. The present work, after providing a survey of the state of the art in multiobjective optimization, gives new insight into this important mathematical field by consequently taking up the viewpoint of differential geometry. This approach, unprecedented in the literature, very naturally results in a generalized homotopy method for multiobjective optimization which is theoretically well-

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founded and numerically efficient. The power of the new method is demonstrated by solving two real-life problems of industrial optimization. The book presents recent results obtained by the author and is aimed at mathematicians, scientists, students and practitioners interested in optimization and numerical homotopy methods.

Since publication of the first edition of *Computer Relaying for Power Systems* in 1988, computer relays have been widely accepted by power engineers throughout the world and in many countries they are now the protective devices of choice. The authors have updated this new edition with the latest developments in technology and applications such as adaptive relaying, wide area measurements, signal processing, new GPS-based measurement techniques and the application of artificial intelligence to digital relays. New material also includes sigma-delta and oversampling A/D converters, self-polarizing and cross-polarizing in transmission lines protection and optical current and voltage transformers. Phadke and Thorp have been working together in power systems engineering for more than 30 years. Their impressive work in the field has been recognized by numerous awards, including the prestigious 2008 Benjamin Franklin Medal in Electrical Engineering for their pioneering contributions to the development and application of microprocessor controllers in electric power systems. Provides the student with an understanding of computer relaying Authored by international authorities in computer relaying Contents include relaying practices, mathematical basis for protective relaying algorithms, transmission line relaying, protection of transformers, machines and buses, hardware organization in integrated systems, system relaying and control, and developments in new relaying principles Features numerous solved examples to explain several of the more complex topics, as well as a problem at the end of each chapter Includes an updated list of references and a greatly expanded subject index.

It is an incontestable fact that numerical analysis techniques are used routinely (although not always effectively) in virtually every quantitative field of scientific endeavor. In this book, which is directed toward upper-division and graduate level students in engineering and mathematics, we have selected for discussion subjects that are traditionally found in numerical analysis texts. But our choice of methodology rejects the traditional where analysis and experience clearly warrant such a departure, and one of our primary aspirations in this work is to equip the reader with the wherewithal to apply numerical analysis thinking to nontraditional subjects. For there is a plethora of computer-oriented sciences such as optimization, statistics, and system analysis and identification that are sorely in need of methods comparable to those related here for classical numerical analysis problems. Toward uncovering for the reader the structure of numerical methods we have, for example, devoted a chapter to a metric space theory for iterative application of operators. In this chapter, we have collected those definitions and concepts of real and functional analysis that are requisite to a modern intermediate-level exposition of the principles of numerical analysis. Further, we derive the abstract theory (most notably, the contraction mapping theorem) for iteration processes.

With distributed generation interconnection power flow becoming bidirectional, culminating in network problems, smart grids aid in electricity generation, transmission, substations, distribution and consumption to achieve a system that is clean, safe (protected), secure, reliable, efficient, and sustainable. This book illustrates fault analysis, fuses, circuit breakers, instrument transformers, relay technology, transmission lines protection setting using DIGSILENT Power Factory. Intended audience is senior undergraduate and graduate students, and researchers in power systems, transmission and distribution, protection system broadly under electrical engineering.

The protective relay industry has kept pace with the technological advancements in the field. Currently, the industry is introducing digital/numerical relays as they provide sub-station protection, control and communication, and the recording of disturbances and faults. Digital/Numerical Relays addresses the urgent based need of manufacturers and users



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adopting this latest technology. Besides covering the current developments, the book also covers current research as well as commercial application of digital/numerical relays. More than ninety case studies shed new light on power system phenomena and power system disturbances. Based on the author's four decades of experience, this book enables readers to implement systems in order to monitor and perform comprehensive analyses of power system disturbances. Most importantly, readers will discover the latest strategies and techniques needed to detect and resolve problems that could lead to blackouts to ensure the smooth operation and reliability of any power system. Logically organized, *Disturbance Analysis for Power Systems* begins with an introduction to the power system disturbance analysis function and its implementation. The book then guides readers through the causes and modes of clearing of phase and ground faults occurring within power systems as well as power system phenomena and their impact on relay system performance. The next series of chapters presents more than ninety actual case studies that demonstrate how protection systems have performed in detecting and isolating power system disturbances in: Generators Transformers Overhead transmission lines Cable transmission line feeders Circuit breaker failures. Throughout these case studies, actual digital fault recording (DFR) records, oscillograms, and numerical relay fault records are presented and analyzed to demonstrate why power system disturbances happen and how the sequence of events are deduced. The final chapter of the book is dedicated to practice problems, encouraging readers to apply what they've learned to perform their own system disturbance analyses. This book makes it possible for engineers, technicians, and power system operators to perform expert power system disturbance analyses using the latest tested and proven methods. Moreover, the book's many cases studies and practice problems make it ideal for students studying power systems.

This 2000 book provided the first detailed exposition of the mathematical theory of boundary integral equations of the first kind on non-smooth domains.

The knowledge of switchgear and apparatus protection plays an important role in the power system. The book is structured to cover the key aspects of the course *Switchgear & Protection* for undergraduate students. The book starts with the discussion of basics of protective relaying. The book includes comprehensive coverage of faults and analysis of symmetrical and unsymmetrical faults. The book explains the protection against overvoltage, lightning arresters and power system earthing. The book covers the characteristics of various types of relays such as electromagnetic relays, induction type relays, directional relays, differential relays, thermal relays, frequency relays and negative sequence relays. The detailed discussion of distance relays and static relays is also included in the book. The book also covers the various possible faults and methods of protection of transformers, generators, motors, busbars and transmission lines. The book further explains the theory of circuit interruption and various arc interruption methods. Finally, the book incorporates various types of circuit breakers, circuit breaker ratings and testing of circuit breakers. The book uses plain and lucid language to explain each topic. The book provides the logical method of explaining the various complicated topics and stepwise methods to make the understanding easy. Each chapter is well supported with necessary illustrations and self-explanatory diagrams. The book explains the philosophy of the subject which makes the understanding of the concepts very clear and makes the subject more interesting.

With emphasis on power system protection from the network operator perspective, this classic textbook explains the fundamentals of relaying and power system phenomena including stability, protection and reliability. The fourth edition brings coverage up-to-

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date with important advancements in protective relaying due to significant changes in the conventional electric power system that will integrate renewable forms of energy and, in some countries, adoption of the Smart Grid initiative. New features of the Fourth Edition include: an entirely new chapter on protection considerations for renewable energy sources, looking at grid interconnection techniques, codes, protection considerations and practices. new concepts in power system protection such as Wide Area Measurement Systems (WAMS) and system integrity protection (SIPS) -how to use WAMS for protection, and SIPS and control with WAMS. phasor measurement units (PMU), transmission line current differential, high voltage dead tank circuit breakers, and relays for multi-terminal lines. revisions to the Bus Protection Guide IEEE C37.234 (2009) and to the sections on additional protective requirements and restoration. Used by universities and industry courses throughout the world, Power System Relaying is an essential text for graduate students in electric power engineering and a reference for practising relay and protection engineers who want to be kept up to date with the latest advances in the industry.

Problems demanding globally optimal solutions are ubiquitous, yet many are intractable when they involve constrained functions having many local optima and interacting, mixed-type variables. The differential evolution (DE) algorithm is a practical approach to global numerical optimization which is easy to understand, simple to implement, reliable, and fast. Packed with illustrations, computer code, new insights, and practical advice, this volume explores DE in both principle and practice. It is a valuable resource for professionals needing a proven optimizer and for students wanting an evolutionary perspective on global numerical optimization.

Emphasizing a practical conception of system unbalances, basic circuits, and calculations, this essential reference/text presents the foundations of symmetrical components with a review of per unit (percent), phasors, and polarity--keeping the mathematics as simple as possible throughout. According to IEEE Electrical Insulation Magazine, this book "...provides students and practicing engineers with a fundamental understanding of the method of symmetrical components and its applications in three-phase electrical systems. . .A useful feature of this book. . .is the incorporation of numerous examples in the text and 30 pages of problems."

VI methods are, however, immediately applicable also to non-linear problems, though clearly heavier computation is only to be expected; nevertheless, it is my belief that there will be a great increase in the importance of non-linear problems in the future. As yet, the numerical treatment of differential equations has been investigated far too little, both in theoretical and practical respects, and approximate methods need to be tried out to a far greater extent than hitherto; this is especially true of partial differential equations and non linear problems. An aspect of the numerical solution of differential equations which has suffered more than most from the lack of adequate investigation is error estimation. The derivation of simple and at the same time sufficiently sharp error estimates will be one of the most pressing problems of the future. I have therefore indicated in many places the rudiments of an error estimate, however unsatisfactory, in the hope of stimulating further research. Indeed, in this respect the book can only be regarded as an introduction. Many readers would perhaps have welcomed assessments of the

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individual methods. At some points where well-trying methods are dealt with I have made critical comparisons between them; but in general I have avoided passing judgement, for this requires greater experience of computing than is at my disposal.

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