THE NUMERICAL SOLUTION OF FREDHOLM INTEGRAL EQUATIONS OF THE SECOND KIND*

KENDALL E. ATKINSON†

1. Introduction. A general method is presented for the numerical solution of the Fredholm integral equation,

$$(1) \qquad \lambda x(s) - \int_a^b K(s, t)x(t)\, dt = y(s), \qquad a \leq s \leq b.$$

In the equation, λ is a nonzero complex number, $[a, b]$ is a finite interval, $y(s)$ is complex-valued and continuous on $[a, b]$, and the integral operator $\mathcal{K}$,

$$(2) \qquad (\mathcal{K}x)(s) = \int_a^b K(s, t)x(t)\, dt, \qquad a \leq s \leq b,$$

is assumed to be a compact (completely continuous) operator on $C[a, b]$ into $C[a, b]$. The set $C[a, b]$ consists of all complex-valued continuous functions on $[a, b]$, and with the maximum norm,

$$\|x\| = \max_{a \leq s \leq b} |x(s)|,$$

it is a Banach space.

Although quite general, the method presented is intended to treat (1) when the kernel $K(s, t)$ has singularities, e.g.,

$$\log |s - t|, \quad |s - t|^{\alpha} \quad \text{for} \quad \alpha > -1, \quad \log |\cos s - \cos t|.$$

When the kernel has several continuous derivatives, the method reduces to replacing the integral with a numerical integral and then to solving a finite linear system; see [1], [2], [3], [5], [11], [13].

In the following section, a generalized form of numerical integration is given for functions of one variable. It is applied to (1) in §3, and convergence of the resulting method is shown in §4. Section 5 contains computational notes and a numerical example.

2. Generalized quadrature. Assume $f \in C[a, b]$ and $\varphi(t)$ is Lebesgue integrable on $[a, b]$; denote $\int_a^b |\varphi(t)|\, dt$ by $\|\varphi\|_1$. (For most practical prob-

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Numerical Solution Of Integral Equations Of The Second Kind

Zhongying Chen,Charles A. Micchelli,Yuesheng Xu

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The Numerical Solution of Integral Equations of the Second Kind Kendall E. Atkinson,1997-06-28 This book provides an extensive introduction to the numerical solution of a large class of integral equations **The Application and Numerical Solution of Integral Equations** R.S. Anderssen,F.R. de Hoog,M.A. Lukas,1980-03-31 This publication reports the proceedings of a one day seminar on The Application and Numerical Solution of Integral Equations held at the Australian National University on Wednesday November 29 1978 It was organized by the Computing Research Group Australian National University and the Division of Mathematics and Statistics CSIRO Due to unforeseen circumstances Dr M L Dow was unable to participate At short notice Professor D Elliott reviewed Cauchy singular integral equations but a paper on same is not included in these proceedings The interested reader is referred to the recent translation of V V Ivanov The Theory of Approximate Methods and their Application to the Numerical Solution of Singular Integral Equations Noordhoff International Publishers Leyden 1976 An attempt was made to structure the program to the extent that the emphasis was on the numerical solution of integral equations for which known applications exist along with explanations of how and why integral equation formalisms arise In addition the programme reflected the broad classification of most integral equations as either singular or non singular as either Fredholm or Volterra and as either first or second kind **Numerical Solution of Integral Equations** Michael A. Golberg,2013-11-11 In 1979 I edited Volume 18 in this series Solution Methods for Integral Equations Theory and Applications Since that time there has been an explosive growth in all aspects of the numerical solution of integral equations By my estimate over 2000 papers on this subject have been published in the last decade and more than 60 books on theory and applications have appeared In particular as can be seen in many of the chapters in this book integral equation techniques are playing an increas ingly important role in the solution of many scientific and engineering problems For instance the boundary element method discussed by Atkinson in Chapter 1 is becoming an equal partner with finite element and finite difference techniques for solving many types of partial differential equations Obviously in one volume it would be impossible to present a complete picture of what has taken place in this area during the past ten years Consequently we have chosen a number of subjects in which significant advances have been made that we feel have not been covered in depth in other books For instance ten years ago the theory of the numerical solution of Cauchy singular equations was in its infancy Today as shown by Golberg and Elliott in Chapters 5 and 6 the theory of polynomial approximations is essentially complete although many details of practical implementation remain to be worked out **Methods for the Numerical Solution of Integral Equations of the Second Kind** David Blair Coldrick,1972 **Computational Methods for Linear Integral Equations** Prem Kythe,Pratap Puri,2011-06-28 This book presents numerical methods and computational aspects for linear integral equations Such equations occur in various areas of applied mathematics physics and engineering The material covered in this book though not exhaustive offers useful techniques for solving a variety of

problems Historical information cover ing the nineteenth and twentieth centuries is available in fragments in Kantorovich and Krylov 1958 Anselone 1964 Mikhlin 1967 Lonseth 1977 Atkinson 1976 Baker 1978 Kondo 1991 and Brunner 1997 Integral equations are encountered in a variety of applications in many fields including continuum mechanics potential theory geophysics electricity and mag netism kinetic theory of gases hereditary phenomena in physics and biology renewal theory quantum mechanics radiation optimization optimal control sys tems communication theory mathematical economics population genetics queue ing theory and medicine Most of the boundary value problems involving differ ential equations can be converted into problems in integral equations but there are certain problems which can be formulated only in terms of integral equations A computational approach to the solution of integral equations is therefore an essential branch of scientific inquiry   Handbook of Computational Methods for Integration Prem K. Kythe,Michael R. Schäferkotter,2004-12-20 During the past 20 years there has been enormous productivity in theoretical as well as computational integration Some attempts have been made to find an optimal or best numerical method and related computer code to put to rest the problem of numerical integration but the research is continuously ongoing as this problem is still very much open ended The importance of numerical integration in so many areas of science and technology has made a practical up to date reference on this subject long overdue The Handbook of Computational Methods for Integration discusses quadrature rules for finite and infinite range integrals and their applications in differential and integral equations Fourier integrals and transforms Hartley transforms fast Fourier and Hartley transforms Laplace transforms and wavelets The practical applied perspective of this book makes it unique among the many theoretical books on numerical integration and quadrature It will be a welcomed addition to the libraries of applied mathematicians scientists and engineers in virtually every discipline   Computational Methods for Integral Equations L. M. Delves,J. L. Mohamed,1985 This textbook provides a readable account of techniques for numerical solutions   Multidimensional Weakly Singular Integral Equations Gennadi Vainikko,2006-11-15 The final aim of the book is to construct effective discretization methods to solve multidimensional weakly singular integral equations of the second kind on a region of Rn e g equations arising in the radiation transfer theory To this end the smoothness of the solution is examined proposing sharp estimates of the growth of the derivatives of the solution near the boundary G The superconvergence effect of collocation methods at the collocation points is established This is a book for graduate students and researchers in the fields of analysis integral equations mathematical physics and numerical methods No special knowledge beyond standard undergraduate courses is assumed   Applied Singular Integral Equations B. N. Mandal,A. Chakrabarti,2016-04-19 The book is devoted to varieties of linear singular integral equations with special emphasis on their methods of solution It introduces the singular integral equations and their applications to researchers as well as graduate students of this fascinating and growing branch of applied mathematics   Stress Concentration at Notches Mykhaylo P. Savruk,Andrzej Kazberuk,2016-09-27 This book compiles solutions of linear theory of elasticity problems for isotropic and anisotropic bodies

with sharp and rounded notches It contains an overview of established and recent achievements and presents the authors original solutions in the field considered with extensive discussion The volume demonstrates through numerous useful examples the effectiveness of singular integral equations for obtaining exact solutions of boundary problems of the theory of elasticity for bodies with cracks and notches Incorporating analytical and numerical solutions of the problems of stress concentrations in solid bodies with crack like defects this volume is ideal for scientists and PhD students dealing with the problems of theory of elasticity and fracture mechanics *Advances in Fuzzy Integral and Differential Equations* Tofigh Allahviranloo,Soheil Salahshour,2021-07-25 As the title of the book suggests the topics of this book are organized into two parts The first part points out the fuzzy differential equations and the second one is related to the fuzzy integral equations The book contains nine chapters that six chapters are about fuzzy differential equations and three of them are about fuzzy integral equations In each part the chapters authors are going to discuss the topics theoretically and numerically All researchers and students in the field of mathematical computer and also engineering sciences can benefit from the subjects of the book **Fractional Order Processes** Seshu Kumar Damarla,Madhusree Kundu,2018-09-03 The book presents efficient numerical methods for simulation and analysis of physical processes exhibiting fractional order FO dynamics The book introduces FO system identification method to estimate parameters of a mathematical model under consideration from experimental or simulated data A simple tuning technique which aims to produce a robust FO PID controller exhibiting iso damping property during re parameterization of a plant is devised in the book A new numerical method to find an equivalent finite dimensional integer order system for an infinite dimensional FO system is developed in the book The book also introduces a numerical method to solve FO optimal control problems Key features Proposes generalized triangular function operational matrices Shows significant applications of triangular orthogonal functions as well as triangular strip operational matrices in simulation identification and control of fractional order processes Provides numerical methods for simulation of physical problems involving different types of weakly singular integral equations Abel s integral equation fractional order integro differential equations fractional order differential and differential algebraic equations and fractional order partial differential equations Suggests alternative way to do numerical computation of fractional order signals and systems and control Provides source codes developed in MATLAB for each chapter allowing the interested reader to take advantage of these codes for broadening and enhancing the scope of the book itself and developing new results **Multiscale Methods for Fredholm Integral Equations** Zhongying Chen,Charles A. Micchelli,Yuesheng Xu,2015-07-16 Presents the state of the art in the study of fast multiscale methods for solving these equations based on wavelets **COMPUTATIONAL MODELS - Volume II** Shaidurov Vladimir Viktorovich,2009-04-10 Computational Models is a component of Encyclopedia of Mathematical Sciences in the global Encyclopedia of Life Support Systems EOLSS which is an integrated compendium of twenty one Encyclopedias Modern Computational Mathematics arises in a wide variety of fields including business economics

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become important tools in science and engineering Several methods have been developed in numerical analysis for equations in mathematical models of applied sciences Widely used methods include Finite Difference Method FDM Finite Element Method FEM Finite Volume Method FVM and Galerkin Method GM Unfortunately none of these are versatile Each has merits and limitations For example the widely used FDM and FEM suffers from difficulties in problem solving when rapid changes appear in singularities Even with the modern computing machines analysis of shock wave or crack propagations in three dimensional solids by the existing classical numerical schemes is challenging computational time memory requirements Therefore with the availability of faster computing machines research into the development of new efficient schemes for approximate solutions numerical simulations is an ongoing parallel activity Numerical methods based on wavelet basis multiresolution analysis may be regarded as a confluence of widely used numerical schemes based on Finite Difference Method Finite Element Method Galerkin Method etc The objective of this monograph is to deal with numerical techniques to obtain multiscale approximate solutions in wavelet basis of different types of integral equations with kernels involving varieties of singularities appearing in the field of elasticity fluid mechanics electromagnetics and many other domains in applied science and engineering *Progress in Intelligent Decision Science* Tofigh Allahviranloo,Soheil Salahshour,Nafiz Arica,2021-01-29 This book contains the topics of artificial intelligence and deep learning that do have much application in real life problems The concept of uncertainty has long been used in applied science especially decision making and a logical decision must be made in the field of uncertainty or in the real life environment that is formed and combined with vague concepts and data The chapters of this book are connected to the new concepts and aspects of decision making with uncertainty Besides other chapters are involved with the concept of data mining and decision making under uncertain computations **Advanced Computing in Industrial Mathematics** Krassimir Georgiev,Michail Todorov,Ivan Georgiev,2018-09-27 This book gathers the peer reviewed proceedings of the 12th Annual Meeting of the Bulgarian Section of the Society for Industrial and Applied Mathematics BGSIAM 17 held in Sofia Bulgaria in December 2017 The general theme of BGSIAM 17 was industrial and applied mathematics with a particular focus on high performance computing numerical methods and algorithms analysis of partial differential equations and their applications mathematical biology control and uncertain systems stochastic models molecular dynamics neural networks genetic algorithms metaheuristics for optimization problems generalized nets and Big Data **Solid Mechanics, Theory of Elasticity and Creep** Holm Altenbach,Suren Manuk Mkhitaryan,Vahram Hakobyan,Avetik Varazdat Sahakyan,2023-02-06 This book presents fundamental theoretical and experimental studies of well known scientists in solid mechanics hydromechanics aeromechanics biomechanics etc These studies relate to contact and mixed problems of the theory of elasticity and viscoelasticity tribology fracture mechanics electroelasticity magnetoelasticity as well as to the theory of anisotropic shells and plates and are aimed at application in various areas of engineering practice The book is devoted to the 110th birthday of academician N Kh

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