

GENERALIZED MOMENT REPRESENTATIONS, BIORTHOGONAL POLYNOMIALS, AND PADÉ APPROXIMANTS

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UDC 517.53

By using the method of generalized moment representations and certain properties of biorthogonal polynomials, we establish new invariance properties of the Padé approximants.

1. Padé Approximants and Generalized Moment Representations

The method of Padé approximants is one of the most efficient and widely used methods for rational approximation of analytic functions. Padé approximants and their applications are studied in numerous papers (see, e.g., the bibliography in [1]).

Definition 1 [1, p. 311]. Assume that a function $f(z)$ can be expanded in a power series of the form

$$f(z) = \sum_{k=0}^{\infty} s_k z^k \quad (1)$$

in a neighborhood of the point $z = 0$. The rational function

$$[M/N]_f(z) = \frac{P_M(z)}{Q_N(z)}, \quad (2)$$

where $P_M(z)$ and $Q_N(z)$ are algebraic polynomials of degree not higher than M and N , respectively, is called the Padé approximant of degree $[M/N]$ for the function $f(z)$ if $f(z) - [M/N]_f(z) = O(z^{M+N+1})$ for $z \rightarrow 0$.

It was shown by Jacobi that the construction of the Padé approximants for functions defined by their power expansions (1) can be reduced to the solution of linear algebraic equations and, hence, approximants (2) can be represented as a ratio of determinants [1, p. 18]. In many cases, however, this approach is not efficient. If $f(z)$ is a Markov function, i.e., if it can be represented in the form of an integral

$$f(z) = \int_{\Delta} \frac{d\mu(r)}{1-zr}, \quad (3)$$

where $\mu(r)$ is a nondecreasing function with infinitely many points of growth on a real interval Δ , then the construction of the Padé approximants of degree $[N-1/N]$, $N \in \mathbb{N}$, for $f(z)$ can be reduced to the construction of polynomials orthogonal on Δ with weight $d\mu(r)$ [2, p. 34].

In 1981, Dzyadyk [3] suggested the method of generalized moment representations, which enables one to construct and investigate the Padé approximants of functions more general than (3).

Institute of Mathematics, Ukrainian Academy of Sciences, Kiev. Translated from *Ukrainskii Matematicheskii Zhurnal*, Vol. 46, No. 10, pp. 1328–1335, October, 1994. Original article submitted June 30, 1993.

Pad Approximants Pad Approximants

A. J. Guttmann



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Partial Differential Equations and Solitary Waves Theory Abdul-Majid Wazwaz, 2010-05-28 Partial Differential Equations and Solitary Waves Theory is a self contained book divided into two parts Part I is a coherent survey bringing together newly developed methods for solving PDEs While some traditional techniques are presented this part does not require thorough understanding of abstract theories or compact concepts Well selected worked examples and exercises shall guide the reader through the text Part II provides an extensive exposition of the solitary waves theory This part handles nonlinear evolution equations by methods such as Hirota's bilinear method or the tanh coth method A self contained treatment is presented to discuss complete integrability of a wide class of nonlinear equations This part presents in an accessible manner a systematic presentation of solitons multi soliton solutions kinks peakons cuspons and compactons While the whole book can be used as a text for advanced undergraduate and graduate students in applied mathematics physics and engineering Part II will be most useful for graduate students and researchers in mathematics engineering and other related fields Dr Abdul Majid Wazwaz is a Professor of Mathematics at Saint Xavier University Chicago Illinois USA

Computational Analysis of Structured Media Simon Gluzman, Vladimir Mityushev, Wojciech Nawalaniec, 2017-09-20 Computational Analysis of Structured Media presents a systematical approach to analytical formulae for the effective properties of deterministic and random composites Schwarz's method and functional equations yield for use in symbolic numeric computations relevant to the effective properties The work is primarily concerned with constructive topics of boundary value problems complex analysis and their applications to composites Symbolic numerical computations are widely used to deduce new formulae interesting for applied mathematicians and engineers The main line of presentation is the investigation of two phase 2D composites with non overlapping inclusions randomly embedded in matrices Computational methodology for main classes of problems in structured media Theory of Representative Volume Element Combines exact results Monte Carlo simulations and Resummation techniques under one umbrella Contains new analytical formulae obtained in the last ten years and it combines different asymptotic methods with the corresponding computer implementations

Polygons, Polyominoes and Polycubes A. J. Guttmann, 2009-05-18 The problem of counting the number of self avoiding polygons on a square grid thereby their perimeter or their enclosed area is a problem that is so easy to state that at first sight it seems surprising that it hasn't been solved It is however perhaps the simplest member of a large class of such problems that have resisted all attempts at their exact solution These are all problems that are easy to state and look as if they should be solvable They include percolation in its various forms the Ising model of ferromagnetism polyomino enumeration Potts models and many others These models are of intrinsic interest to mathematicians and mathematical physicists but can also be applied to many other areas including economics the social sciences the biological sciences and even to traffic models It is the widespread applicability of these models to interesting phenomena that makes them so deserving of our attention Here

however we restrict our attention to the mathematical aspects Here we are concerned with collecting together most of what is known about polygons and the closely related problems of polyominoes We describe what is known taking care to distinguish between what has been proved and what is certainly true but has not been proved The earlier chapters focus on what is known and on why the problems have not been solved culminating in a proof of unsolvability in a certain sense The next chapters describe a range of numerical and theoretical methods and tools for extracting as much information about the problem as possible in some cases permitting exact conjectures to be made

Theory and Simulation of Hard-Sphere Fluids and Related Systems Angel Mulero, 2008-07-09 Hard spheres and related objects hard disks and mixtures of hard systems are paradigmatic systems indeed they have served as a basis for the theoretical and numerical development of a number of fields such as general liquids and fluids amorphous solids liquid crystals colloids and granular matter to name but a few The present volume introduces and reviews some important basics and progress in the study of such systems Their structure thermodynamic properties equations of state as well as kinetic and transport properties are considered from different and complementary points of view This book addresses graduate students lecturers as well as researchers in statistical mechanics physics of liquids physical chemistry and chemical engineering

Pythagorean-Hodograph Curves: Algebra and Geometry Inseparable Rida T Farouki, 2007-10-11 By virtue of their special algebraic structures Pythagorean hodograph PH curves offer unique advantages for computer aided design and manufacturing robotics motion control path planning computer graphics animation and related fields This book offers a comprehensive and self contained treatment of the mathematical theory of PH curves including algorithms for their construction and examples of their practical applications It emphasizes the interplay of ideas from algebra and geometry and their historical origins and includes many figures worked examples and detailed algorithm descriptions

Automata, Languages, and Programming Magnús M. Halldórsson, Kazuo Iwama, Naoki Kobayashi, Bettina Speckmann, 2015-06-19 The two volume set LNCS 9134 and LNCS 9135 constitutes the refereed proceedings of the 42nd International Colloquium on Automata Languages and Programming ICALP 2015 held in Kyoto Japan in July 2015 The 143 revised full papers presented were carefully reviewed and selected from 507 submissions The papers are organized in the following three tracks algorithms complexity and games logic semantics automata and theory of programming and foundations of networked computation models algorithms and information management

Mathematical Methods in Engineering Joseph M. Powers, Mihir Sen, 2015-01-26 This text focuses on a variety of topics in mathematics in common usage in graduate engineering programs including vector calculus linear and nonlinear ordinary differential equations approximation methods vector spaces linear algebra integral equations and dynamical systems The book is designed for engineering graduate students who wonder how much of their basic mathematics will be of use in practice Following development of the underlying analysis the book takes students through a large number of examples that have been worked in detail Students can choose to go through each step or to skip ahead if they so desire

After seeing all the intermediate steps they will be in a better position to know what is expected of them when solving assignments examination problems and when on the job Chapters conclude with exercises for the student that reinforce the chapter content and help connect the subject matter to a variety of engineering problems Students have grown up with computer based tools including numerical calculations and computer graphics the worked out examples as well as the end of chapter exercises often use computers for numerical and symbolic computations and for graphical display of the results

Resurgence, Physics and Numbers Frédéric Fauvet, Dominique Manchon, Stefano Marini, David Sauzin, 2017-11-17 This book is issued from a conference around resurgent functions in Physics and multiple zeta values which was held at the Centro di Ricerca Matematica Ennio de Giorgi in Pisa on May 18-22 2015 This meeting originally stemmed from the impressive upsurge of interest for Jean Ecalle's alien calculus in Physics in the last years a trend that has considerably developed since then The volume contains both original research papers and surveys by leading experts in the field reflecting the themes that were tackled at this event Stokes phenomenon and resurgence in various mathematical and physical contexts but also related constructions in algebraic combinatorics and results concerning numbers specifically multiple zeta values **Delay**

Ordinary and Partial Differential Equations Andrei D. Polyanin, Vsevolod G. Sorokin, Alexei I. Zhurov, 2023-08-28 Delay Ordinary and Partial Differential Equations is devoted to linear and nonlinear ordinary and partial differential equations with constant and variable delay It considers qualitative features of delay differential equations and formulates typical problem statements Exact approximate analytical and numerical methods for solving such equations are described including the method of steps methods of integral transformations method of regular expansion in a small parameter method of matched asymptotic expansions iteration type methods Adomian decomposition method collocation method Galerkin type projection methods Euler and Runge Kutta methods shooting method method of lines finite difference methods for PDEs methods of generalized and functional separation of variables method of functional constraints method of generating equations and more The presentation of the theoretical material is accompanied by examples of the practical application of methods to obtain the desired solutions Exact solutions are constructed for many nonlinear delay reaction diffusion and wave type PDEs that depend on one or more arbitrary functions A review is given of the most common mathematical models with delay used in population theory biology medicine economics and other applications The book contains much new material previously unpublished in monographs It is intended for a broad audience of scientists university professors and graduate and postgraduate students specializing in applied and computational mathematics mathematical physics mechanics control theory biology medicine chemical technology ecology economics and other disciplines Individual sections of the book and examples are suitable for lecture courses on applied mathematics mathematical physics and differential equations for delivering special courses and for practical training *Asymptotic Methods for Engineers* Igor V. Andrianov, Jan

Awrejcewicz, 2024-05-16 Asymptotic Methods for Engineers is based on the authors many years of practical experience in the

application of asymptotic methods to solve engineering problems This book is devoted to modern asymptotic methods AM which is widely used in engineering applied sciences physics and applied mathematics Avoiding complex formal calculations and justifications the book's main goal is to describe the main ideas and algorithms Moreover not only is there a presentation of the main AM but there is also a focus on demonstrating their unity and inseparable connection with the methods of summation and asymptotic interpolation The book will be useful for students and researchers from applied mathematics and physics and of interest to doctoral and graduate students university and industry professors from various branches of engineering mechanical civil electro mechanical etc

Series Expansion Methods for Strongly Interacting Lattice Models Jaan Oitmaa, Chris Hamer, Weihong Zheng, 2006-04-06 A comprehensive guide to series expansion methods for lattice models in theoretical physics

Algorithms for Approximation Armin Iske, Jeremy Levesley, 2006-12-13 Approximation methods are vital in many challenging applications of computational science and engineering This is a collection of papers from world experts in a broad variety of relevant applications including pattern recognition machine learning multiscale modelling of fluid flow metrology geometric modelling tomography signal and image processing It documents recent theoretical developments which have lead to new trends in approximation it gives important computational aspects and multidisciplinary applications thus making it a perfect fit for graduate students and researchers in science and engineering who wish to understand and develop numerical algorithms for the solution of their specific problems An important feature of the book is that it brings together modern methods from statistics mathematical modelling and numerical simulation for the solution of relevant problems with a wide range of inherent scales Contributions of industrial mathematicians including representatives from Microsoft and Schlumberger foster the transfer of the latest approximation methods to real world applications

Intermolecular Interactions Ilya G. Kaplan, 2006-05-01 The subject of this book intermolecular interactions is as important in physics as in chemistry and molecular biology Intermolecular interactions are responsible for the existence of liquids and solids in nature They determine the physical and chemical properties of gases liquids and crystals the stability of chemical complexes and biological compounds In the first two chapters of this book the detailed qualitative description of different types of intermolecular forces at large intermediate and short range distances is presented For the first time in the monographic literature the temperature dependence of the dispersion forces is discussed and it is shown that at finite temperatures the famous Casimir Polder asymptotic formula is correct only at narrow distance range The author has aimed to make the presentation understandable to a broad scope of readers without oversimplification In Chapter 3 the methods of quantitative calculation of the intermolecular interactions are discussed and modern achievements are presented This chapter should be helpful for scientists performing computer calculations of many electron systems The last two chapters are devoted to the many body effects and model potentials More than 50 model potentials exploited for processing experimental data and computer simulation in different fields of physics chemistry and molecular biology are represented The widely used

global optimisation methods simulated annealing diffusion equation method basin hopping algorithm and genetic algorithm are described in detail Significant efforts have been made to present the book in a self sufficient way for readers All the necessary mathematical apparatus including vector and tensor calculus and the elements of the group theory as well as the main methods used for quantal calculation of many electron systems are presented in the appendices **The Schur**

Complement and Its Applications Fuzhen Zhang, 2006-03-30 What's in a name To paraphrase Shakespeare's Juliet that which ilie Haynsworth called the Schur complement by any other name would be just as beautiful Nevertheless her 1968 naming decision in honor of Issai Schur 1875 1941 has gained lasting acceptance by the mathematical community The Schur complement plays an important role in matrix analysis statistics numerical analysis and many other areas of mathematics and its applications Our goal is to expose the Schur complement as a rich and basic tool in mathematical research and applications and to discuss many significant results that illustrate its power and fertility Although our book was originally conceived as a research reference it will also be useful for graduate and upper division undergraduate courses in mathematics applied mathematics and statistics The contributing authors have developed an exposition that makes the material accessible to readers with a sound foundation in linear algebra The eight chapters of the book Chapters 0 7 cover themes and variations on the Schur complement including its historical development basic properties eigenvalue and singular value inequalities matrix inequalities in both finite and infinite dimensional settings closure properties and applications in statistics probability and numerical analysis The chapters need not be read in the order presented and the reader should feel at leisure to browse freely through topics of interest **Mathematical Tools for Physicists** George L.

Trigg, 2006-08-21 Mathematical Tools for Physicists is a unique collection of 18 carefully reviewed articles each one written by a renowned expert working in the relevant field The result is beneficial to both advanced students as well as scientists at work the former will appreciate it as a comprehensive introduction while the latter will use it as a ready reference The contributions range from fundamental methods right up to the latest applications including Algebraic analytic geometric methods Symmetries and conservation laws Mathematical modeling Quantum computation The emphasis throughout is ensuring quick access to the information sought and each article features an abstract a detailed table of contents continuous cross referencing references to the most relevant publications in the field and suggestions for further reading both introductory as well as highly specialized In addition a comprehensive index provides easy access to the vast number of key words extending beyond the range of the headlines **Nonlinear Numerical Methods and Rational Approximation II**

A. Cuyt, 2012-12-06 These are the proceedings of the international conference on Nonlinear numerical methods and Rational approximation II organised by Annie Cuyt at the University of Antwerp Belgium 05 11 September 1993 It was held for the third time in Antwerp at the conference center of UIA after successful meetings in 1979 and 1987 and an almost yearly tradition since the early 70's The following figures illustrate the growing number of participants and their geographical

dissemination In 1993 the Belgian scientific committee consisted of A Bultheel Leuven A Cuyt Antwerp J Meinguet Louvain Ia Neuve and J P Thiran Namur The conference focused on the use of rational functions in different fields of Numer ical Analysis The invited speakers discussed Orthogonal polynomials D S Lu binsky Rational interpolation M Gutknecht Rational approximation E B Saff Pade approximation A Gonchar and Continued fractions W B Jones In contributed talks multivariate and multidimensional problems applications and implementations of each main topic were considered To each of the five main topics a separate conference day was devoted and a separate proceedings chapter compiled accordingly In this way the proceedings reflect the organisation of the talks at the conference Nonlinear numerical methods and rational approximation may be a nar row field for the outside world but it provides a vast playground for the chosen ones It can fascinate specialists from Moscow to South Africa from Boulder in Colorado and from sunny Florida to Zurich in Switzerland Brain Cancer: New Insights for the Healthcare Professional: 2013 Edition ,2013-07-22 Brain Cancer New Insights for the Healthcare Professional 2013 Edition is a ScholarlyEditions book that delivers timely authoritative and comprehensive information about Diagnosis and Screening The editors have built Brain Cancer New Insights for the Healthcare Professional 2013 Edition on the vast information databases of ScholarlyNews You can expect the information about Diagnosis and Screening in this book to be deeper than what you can access anywhere else as well as consistently reliable authoritative informed and relevant The content of Brain Cancer New Insights for the Healthcare Professional 2013 Edition has been produced by the world s leading scientists engineers analysts research institutions and companies All of the content is from peer reviewed sources and all of it is written assembled and edited by the editors at ScholarlyEditions and available exclusively from us You now have a source you can cite with authority confidence and credibility More information is available at <http://www.ScholarlyEditions.com>

CRC Concise Encyclopedia of Mathematics Eric W. Weisstein,2002-12-12 Upon publication the first edition of the CRCConcise Encyclopedia of Mathematics received overwhelming accolades for its unparalleled scope readability and utility It soon took its place among the top selling books in the history of Chapman Hall CRC and its popularity continues unabated Yet also unabated has been the d *Monte Carlo Frameworks* Daniel J. Duffy,Joerg Kienitz,2009-11-02 This is one of the first books that describe all the steps that are needed in order to analyze design and implement Monte Carlo applications It discusses the financial theory as well as the mathematical and numerical background that is needed to write flexible and efficient C code using state of the art design and system patterns object oriented and generic programming models in combination with standard libraries and tools Includes a CD containing the source code for all examples It is strongly advised that you experiment with the code by compiling it and extending it to suit your needs Support is offered via a user forum on www.datasimfinancial.com where you can post queries and communicate with other purchasers of the book This book is for those professionals who design and develop models in computational finance This book assumes that you have a working knowledge of C *Using R for Numerical Analysis in Science and Engineering* Victor A. Bloomfield,2018-09-03 Instead of

presenting the standard theoretical treatments that underlie the various numerical methods used by scientists and engineers Using R for Numerical Analysis in Science and Engineering shows how to use R and its add on packages to obtain numerical solutions to the complex mathematical problems commonly faced by scientists and engineers This practical guide to the capabilities of R demonstrates Monte Carlo stochastic deterministic and other numerical methods through an abundance of worked examples and code covering the solution of systems of linear algebraic equations and nonlinear equations as well as ordinary differential equations and partial differential equations It not only shows how to use R s powerful graphic tools to construct the types of plots most useful in scientific and engineering work but also Explains how to statistically analyze and fit data to linear and nonlinear models Explores numerical differentiation integration and optimization Describes how to find eigenvalues and eigenfunctions Discusses interpolation and curve fitting Considers the analysis of time series Using R for Numerical Analysis in Science and Engineering provides a solid introduction to the most useful numerical methods for scientific and engineering data analysis using R

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