

Hermite-Padé rational approximation to irrational numbers *

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Abstract

We will describe a method for proving that a given real number is irrational. It amounts to constructing explicit rational approximants to the real number which are better than possible in case the number is rational. The rational approximants are obtained by evaluating a Hermite-Padé rational approximant to explicit functions at a convenient (integer) point. This constructive proof can also be used to prove linear independence over \mathbb{Q} of some real numbers and in fact was first used by Hermite to prove the transcendence of e . The method is illustrated by various examples involving the zeta-function.

1 Introduction

Most real numbers are irrational, yet it is not straightforward to give examples of irrational numbers. Surely, algebraic numbers come to mind, but their number is countable as well. Only a few remarkable mathematical constants are known to be irrational. The algebraic number $\sqrt{2}$ is irrational and the most common proof (using contradiction and simple properties of odd and even numbers) is very instructive, even at pre-university level. The proof allegedly goes back to the Pythagoreans, which were in fact not so happy to find that the lengths of some lines in a square (the diagonal and the sides) are incommensurable (i.e., their ratio is not a rational number). The base of the natural logarithm, Euler's number e , is more interesting and Euler seems to be the first for proving its irrationality. Euler used continued fractions [13] and obtained an infinite regular continued fraction for e , which proves its irrationality. Another proof uses the Taylor approximation

$$e^x = \sum_{k=0}^n \frac{x^k}{k!} + \frac{e^x}{(n+1)!}, \quad \xi \in (0, x),$$

for $x = 1$. Since $0 < e^x < x < 3$, this gives

$$0 < n! \left(e - \sum_{k=0}^n \frac{1}{k!} \right) < \frac{3}{n+1}. \quad (1.1)$$

*Thanks to Eyyasjallajökull for enabling me to finish this paper. This research was supported by FWO grant G.0427.09 and K.U.Leuven research grant OT/08/063.

Pade Rational Approximation Theory A

C. K. Chui, G. G. Lorentz

Pade Rational Approximation Theory A:

Pade and Rational Approximation E.B. Safe,2013-05-09 Pad and Rational Approximation Theory and Applications presents the proceedings of the Conference on Rational Approximation with Emphasis on Applications of Pad Approximants held in Tampa Florida on December 15 17 1976 The contributors focus on the interplay of theory computation and physical applications This book is composed of six parts encompassing 44 chapters The introductory part discusses the general theory of orthogonal polynomials that is the mathematical basis of Pad approximants and related matters evaluation This text also examines the connection between approximants on a stepline in the ordinary Pad table and certain continued fractions and the convergence of diagonal Pad approximants to a class of functions with an even number of branch points The following parts deal with the special functions and continued fractions of Pad approximation and the theory of rational approximations These parts also investigate the geometric convergence of Chebyshev rational approximation on the half line the optimal approximation by Almost Classical interpolation and the incomplete polynomials approximation The discussion then shifts to the physical applications and computations of the Pad approximants The concluding part presents the applications of rational approximation to gun fire control and to the White Sands Missile Range Computer Facility This part also provides a list of some open problems and conjectures concerning polynomials and rational functions This book is of great benefit to mathematicians physicists and laboratory workers

Padé and rational approximation : theory and applications :

(proceedings of the Conference on rational approximation with emphasis on applications of Padé approximants) : international symposium; Tampa - Fl., December 15-17, 1976 Richard S. Varga,Edward B. Saff,1977

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Rational Approximation E. B. Saff,Richard S. Varga,1977 *Padé and rational approximation : theory and applications ; [proceedings of an international symposium held at the University of South Florida, Tampa, Florida, December 15 - 17, 1976]* Edward Barry Saff,1977

Padé Approximation and Its Applications ,1973

Padé Approximants George Allen

Baker,Peter Graves-Morris,1996-01-26 The first edition of this book was reviewed in 1982 as the most extensive treatment of Padé approximants actually available This second edition has been thoroughly updated with a substantial new chapter on multiseries approximants Applications to statistical mechanics and critical phenomena are extensively covered and there are newly extended sections devoted to circuit design matrix Padé approximation and computational methods This succinct and straightforward treatment will appeal to scientists engineers and mathematicians alike

Padé and Rational Approximation: Theory and Applications : Proceedings E. B. Saff,Richard S. Varga,1977

Padé Approximation and its Applications L.

Wuytack,2006-11-15 *Multidimensional Systems Theory and Applications* N.K. Bose,2013-12-20 Preface to Second Edition

From the time that the original edition was published in 1985 multidimensional systems theory has matured into a discipline of research and teaching with an expanding array of applications The international journal on Multidimensional Systems and Signal Processing founded in 1990 is now in its fourteenth year A biannual international workshop on n D systems was

launched in 1998 and the impressive number of special sessions mini symposia monographs and special issues that have emerged bear testimony to the growing popularity and importance of the subject matter among scientists in various disciplines including engineering computer science geophysics and mathematics This second edition builds on the fundamentals expounded in the original book with the addition of important developments in theory as well as practice since 1985 Particular attention has been given to the consolidation of basic results unification of theory and the diversification of applications Chapters that remain have been reordered and updated in content and references Some chapters considered to be somewhat outdated have been replaced with newer proven as well as potentially significant results inspired by some groundbreaking research and directions which are likely to stimulate further research In addition to the description of some challenging open problems posed in 1985 which have since been solved new problems yet to be tackled are also included

Energy Research Abstracts ,1979-05 Approximation Theory VI C. K. Chui,Larry L. Schumaker,J. D. Ward,1989

Approximation Theory VII Elliott Ward Cheney,C. K. Chui,Larry L. Schumaker,1993 **Encyclopaedia of Mathematics** Michiel Hazewinkel,2012-12-06 This ENCYCLOPAEDIA OF MATHEMATICS aims to be a reference work for all parts of mathematics It is a translation with updates and editorial comments of the Soviet Mathematical Encyclopaedia published by Soviet Encyclopaedia Publishing House in five volumes in 1977 1985 The annotated translation consists of ten volumes including a special index volume There are three kinds of articles in this ENCYCLOPAEDIA First of all there are survey type articles dealing with the various main directions in mathematics where a rather fine subdivision has been used The main requirement for these articles has been that they should give a reasonably complete up to date account of the current state of affairs in these areas and that they should be maximally accessible On the whole these articles should be understandable to mathematics students in their first specialization years to graduates from other mathematical areas and depending on the specific subject to specialists in other domains of science engineers and teachers of mathematics These articles treat their material at a fairly general level and aim to give an idea of the kind of problems techniques and concepts involved in the area in question They also contain background and motivation rather than precise statements of precise theorems with detailed definitions and technical details on how to carry out proofs and constructions The second kind of article of medium length contains more detailed concrete problems results and techniques **Energy Research Abstracts** ,1979 Semiannual with semiannual and annual indexes References to all scientific and technical literature coming from DOE its laboratories energy centers and contractors Includes all works deriving from DOE other related government sponsored information and foreign nonnuclear information Arranged under 39 categories e g Biomedical sciences basic studies Biomedical sciences applied studies Health and safety and Fusion energy Entry gives bibliographical information and abstract Corporate author subject report number indexes Applications Of Padé' Approximation Theory In Fluid Dynamics Amilcare Pozzi,1994-03-07 Although Padé presented his fundamental paper at the end of the last century the studies on Padé's

approximants only became significant in the second part of this century Pad procedure is related to the theory of continued fractions and some convergence theorems can be expressed only in terms of continued fractions Further Pad approximants have some advantages of practical applicability with respect to the continued fraction theory Moreover as Chisholm notes a given power series determines a set of approximants which are usually unique whereas there are many ways of writing an associated continued fraction The principal advantage of Pad approximants with respect to the generating Taylor series is that they provide an extension beyond the interval of convergence of the series Pad approximants can be applied in many parts of fluid dynamics both in steady and in nonsteady flows both in incompressible and in compressible regimes This book is divided into four parts The first one deals with the properties of the Pad approximants that are useful for the applications and illustrates with the aid of diagrams and tables the effectiveness of this technique in the field of applied mathematics The second part recalls the basic equations of fluid dynamics those associated with the names of Navier Stokes Euler and Prandtl and gives a quick derivation of them from the general balance equation The third shows eight examples of the application of Pad approximants to steady flows also taking into account the influence of the coupling of heat conduction in the body along which a fluid flows with conduction and convection in the fluid itself The fourth part considers two examples of the application of Pad approximants to unsteady flows

Approximation Theory and Applications Zvi Ziegler, 1981 Construction of elements of the relative chebyshev center The numerical claculation of spline approximations on a binfinite Global analysis in nonlinear approximation and its application to exponential approximation Global analysis in nonlinear approximation and its application to exponential approximation Simultaneous approximation and restricted chebyshev centers in function spaces

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Open problems **Approximation Theory** V C. K. Chui,Larry L. Schumaker,J. D. Ward, 1986 **Approximation Theory** Carl De Boor,American Mathematical Society,1986-12-31 The papers in this book first presented at a 1986 AMS Short Course give a brief introduction to approximation theory and some of its current areas of active research both theoretical and applied The first lecture describes and illustrates the basic concerns of the field Topics highlighted in the other lectures

include the following approximation in the complex domain N width optimal recovery interpolation algorithms for approximation and splines with a strong emphasis on a multivariate setting for the last three topics The book is aimed at mathematicians interested in an introduction to areas of current research and to engineers and scientists interested in exploring the field for possible applications to their own fields The book is best understood by those with a standard first graduate course in real and complex analysis but some of the presentations are accessible with the minimal requirements of advanced calculus and linear algebra

Extrapolation and Rational Approximation Claude Brezinski, Michela Redivo-Zaglia, 2020-11-30

This book paints a fresco of the field of extrapolation and rational approximation over the last several centuries to the present through the works of their primary contributors It can serve as an introduction to the topics covered including extrapolation methods Pad approximation orthogonal polynomials continued fractions Lanczos type methods etc it also provides in depth discussion of the many links between these subjects A highlight of this book is the presentation of the human side of the fields discussed via personal testimonies from contemporary researchers their anecdotes and their exclusive remembrances of some of the actors This book shows how research in this domain started and evolved Biographies of other scholars encountered have also been included An important branch of mathematics is described in its historical context opening the way to new developments After a mathematical introduction the book contains a precise description of the mathematical landscape of these fields spanning from the 19th century to the first part of the 20th After an analysis of the works produced after that period in particular those of Richardson Aitken Shanks Wynn and others the most recent developments and applications are reviewed

Approximation Theory and Functional Analysis C. K. Chui, G. G.

Lorentz, 1991 This volume surveys the fields of approximation theory and functional analysis Compiled in honour of G G Lorenz regarded as the father of modern approximation theory it consists of invited papers representing up to date research by leading mathematicians in these fields

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