

Approximations in Fourier transforms

By D. A. Bell

This paper discusses the possibility of obtaining the Fourier transform of an arbitrary function, which is given in numerical or graphical form, by approximating it piece-wise with simple analytic functions.

The Fourier transform is a necessary tool for translation between the time-function and frequency-function description of a waveform, or between linear distribution of intensity across an aperture and angular distribution of radiation from the aperture. If the function to be transformed is of reasonably simple analytical form, there is no difficulty; one has merely to consult a table of Fourier transforms such as was produced by Campbell and Foster (1948). But if the subject to be transformed is a set of experimental data, not conforming precisely to any analytical law, the problem is less easy. The direct approach is to perform numerically the integration

$\int f(t) \left(\frac{\sin}{\cos} \right) \omega t dt$ for a sufficient number of values of ω ,

and in general for both sine and cosine transforms. This is practicable with an electronic computer (see Appendix), but not by hand if many frequencies are required.

An alternative is to approximate the arbitrary function by one or more analytical functions of which the transforms are available. Since Fourier transforms are additive, the difference between the transform of the approximation $f'(t)$ and of the true function $f(t)$ will be the transform of the error in fit of the approximation:

$$F'(\omega) - F(\omega) = \int [f'(t) - f(t)] \left(\frac{\sin}{\cos} \right) \omega t dt. \quad (1)$$

For a rough estimate of the error, note that the zero-frequency cosine component of the error (i.e. the "d.c." component) is the area between the two curves. It is also likely that the next largest component will be such that a half wave extends between two points of exact fit, since a half sine wave may be a first approximation to the error distribution. Since the Fourier representation of a well-behaved function has components which in general trend have amplitudes decaying at least in inverse proportion to the order of the harmonic, the order of magnitude of the higher-frequency components can also be estimated. The simplest example of this technique, approximating the arbitrary function piece-wise by straight lines, was used by Pucel (1957) in a filter design problem; but there is no need to restrict the approximating function to a linear form. As an example, suppose the series of dots in Fig. 1 represents experimental data, and the cosine Fourier transform of

the corresponding curve is required. (In fact these points are all taken from a very simple function, so that it will be possible to compare the exact transform with the approximation.) The ranges of the approximations chosen are indicated by the crosses; the first rather highly curved section is approximated by

$$f_1(t) = 3.5 + 0.98 \cos t \quad 0 < t < 1 \quad (2)$$

and subsequent sections are approximated by straight lines joining the transition points

$$\left. \begin{aligned} f_2(t) &= 5.33 - 1.3 t & 1 < t < 1.5 \\ f_3(t) &= 5.96 - 1.72 t & 1.5 < t < 2.0 \\ f_4(t) &= 7.06 - 2.28 t & 2 < t < 2.5 \\ f_5(t) &= 8.28 - 2.76 t & 2.5 < t < 3.0 \end{aligned} \right\} \quad (3)$$

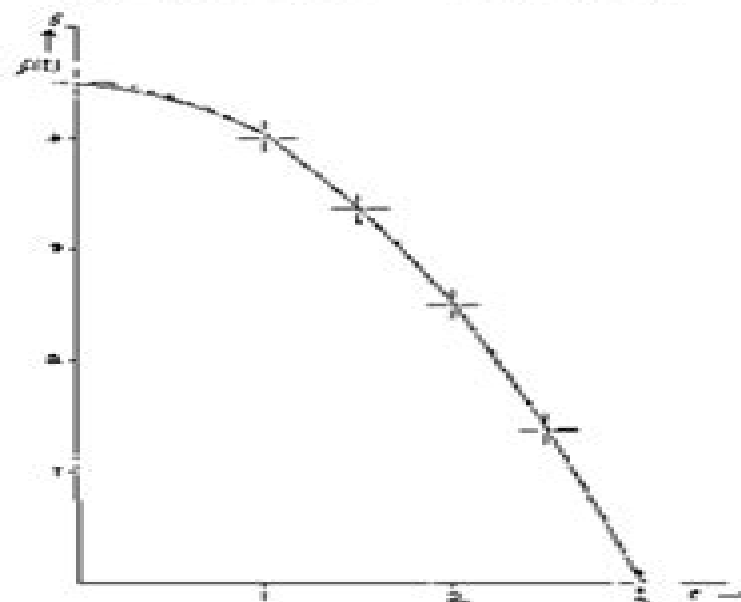


Fig. 1.—Example of a set of points and piece-wise approximating functions

Fourier Transforms And Approximations

Holger Wendland



Fourier Transforms And Approximations:

Fourier Transforms and Approximations A M Sedletsii, 2000-09-20 Three classes of Fourier transforms are presented Fourier Laplace transforms on the halflin Fourier transforms of measures with compact support and Fourier transforms of rapidly decreasing functions on whole line The focus is on the behaviour of Fourier transforms in the region of analyticity and the distribution of their zeros Application Fourier Analysis and Approximation P.L. Butzer, Nessel, Trebels, 2012-12-06 At the international conference on Harmonic Analysis and Integral Transforms conducted by one of the authors at the Mathematical Research Institute in Oberwolfach Black Forest in August 1965 it was felt that there was a real need for a book on Fourier analysis stressing i parallel treatment of Fourier series and Fourier transforms from a transform point of view ii treatment of Fourier transforms in L^p space not only for $p=1$ and $p=2$ iii classical solution of partial differential equations with completely rigorous proofs iv theory of singular integrals of convolution type v applications to approximation theory including saturation theory vi multiplier theory vii Hilbert transforms Riesz fractional integrals Bessel potentials viii Fourier transform methods on locally compact groups This study aims to consider these aspects presenting a systematic treatment of Fourier analysis on the circle as well as on the infinite line and of those areas of approximation theory which are in some way or other related thereto A second volume is in preparation which goes beyond the one dimensional theory presented here to cover the subject for functions of several variables Approximately a half of this first volume deals with the theories of Fourier series and of Fourier integrals from a transform point of view *Fourier Analysis of Numerical Approximations of Hyperbolic Equations* R. Vichnevetsky, J. B. Bowles, 1982-01-01 There has been a growing interest in the use of Fourier analysis to examine questions of accuracy and stability of numerical methods for solving partial differential equations This kind of analysis can produce particularly attractive and useful results for hyperbolic equations This book provides useful reference material for those concerned with computational fluid dynamics for physicists and engineers who work with computers in the analysis of problems in such diverse fields as hydraulics gas dynamics plasma physics numerical weather prediction and transport processes in engineering and who need to understand the implications of the approximations they use and for applied mathematicians concerned with the more theoretical aspects of these computations **A First Course in Fourier Analysis** David W. Kammler, 2008-01-17 This book provides a meaningful resource for applied mathematics through Fourier analysis It develops a unified theory of discrete and continuous univariate Fourier analysis the fast Fourier transform and a powerful elementary theory of generalized functions and shows how these mathematical ideas can be used to study sampling theory PDEs probability diffraction musical tones and wavelets The book contains an unusually complete presentation of the Fourier transform calculus It uses concepts from calculus to present an elementary theory of generalized functions FT calculus and generalized functions are then used to study the wave equation diffusion equation and diffraction equation Real world applications of Fourier analysis are described in the chapter on

musical tones A valuable reference on Fourier analysis for a variety of students and scientific professionals including mathematicians physicists chemists geologists electrical engineers mechanical engineers and others

Fourier Analysis and Approximation of Functions Roald M. Trigub, Eduard S. Belinsky, 2004-09-07 In Fourier Analysis and Approximation of Functions basics of classical Fourier Analysis are given as well as those of approximation by polynomials splines and entire functions of exponential type In Chapter 1 which has an introductory nature theorems on convergence in that or another sense of integral operators are given In Chapter 2 basic properties of simple and multiple Fourier series are discussed while in Chapter 3 those of Fourier integrals are studied The first three chapters as well as partially Chapter 4 and classical Wiener Bochner Bernstein Khintchin and Beurling theorems in Chapter 6 might be interesting and available to all familiar with fundamentals of integration theory and elements of Complex Analysis and Operator Theory Applied mathematicians interested in harmonic analysis and or numerical methods based on ideas of Approximation Theory are among them In Chapters 6 11 very recent results are sometimes given in certain directions Many of these results have never appeared as a book or certain consistent part of a book and can be found only in periodicals looking for them in numerous journals might be quite onerous thus this book may work as a reference source The methods used in the book are those of classical analysis

Fourier Analysis in finite dimensional Euclidean space Diophantine Analysis and random choice

Fast and approximate computation of Laplace and Fourier transforms Ines Melzer, 2016-03-20 In this thesis we treat the computation of transforms with asymptotically smooth and oscillatory kernels We introduce the discrete Laplace transform in a modern form including a generalization to more general kernel functions These more general kernels lead to specific function transforms Moreover we treat the butterfly fast Fourier transform Based on a local error analysis we develop a rigorous error analysis for the whole butterfly scheme In the final part of the thesis the Laplace and Fourier transform are combined to a fast Fourier transform for nonequispaced complex evaluation nodes All theoretical results on accuracy and computational complexity are illustrated by numerical experiments

Fourier Analysis and Approximation, 2011-09-21 Fourier Analysis and Approximation

Numerical Fourier Analysis Gerlind Plonka, Daniel Potts, Gabriele Steidl, Manfred Tasche, 2023-11-08 New technological innovations and advances in research in areas such as spectroscopy computer tomography signal processing and data analysis require a deep understanding of function approximation using Fourier methods To address this growing need this monograph combines mathematical theory and numerical algorithms to offer a unified and self contained presentation of Fourier analysis The first four chapters of the text serve as an introduction to classical Fourier analysis in the univariate and multivariate cases including the discrete Fourier transforms providing the necessary background for all further chapters Next chapters explore the construction and analysis of corresponding fast algorithms in the one and multidimensional cases The well known fast Fourier transforms FFTs are discussed as well as recent results on the construction of the nonequispaced FFTs high dimensional FFTs on special lattices and sparse FFTs An additional chapter is

devoted to discrete trigonometric transforms and Chebyshev expansions The final two chapters consider various applications of numerical Fourier methods for improved function approximation including Prony methods for the recovery of structured functions This new edition has been revised and updated throughout featuring new material on a new Fourier approach to the ANOVA decomposition of high dimensional trigonometric polynomials new research results on the approximation errors of the nonequispaced fast Fourier transform based on special window functions and the recently developed ESPIRA algorithm for recovery of exponential sums among others Numerical Fourier Analysis will be of interest to graduate students and researchers in applied mathematics physics computer science engineering and other areas where Fourier methods play an important role in applications

Fourier Analysis and Approximation Paul Leo Butzer, Rolf Joachim Nessel, 1971 The DFT William L. Briggs, Van Emden Henson, 1995-01-01 This book explores both the practical and theoretical aspects of the Discrete Fourier Transform one of the most widely used tools in science engineering and computational mathematics Designed to be accessible to an audience with diverse interests and mathematical backgrounds the book is written in an informal style and is supported by many examples figures and problems Conceived as an owner's manual this comprehensive book covers such topics as the history of the DFT derivations and properties of the DFT comprehensive error analysis issues concerning the implementation of the DFT in one and several dimensions symmetric DFTs a sample of DFT applications and an overview of the FFT

Scattered Data Approximation Holger Wendland, 2004-12-13 Many practical applications require the reconstruction of a multivariate function from discrete unstructured data This book gives a self contained complete introduction into this subject It concentrates on truly meshless methods such as radial basis functions moving least squares and partitions of unity The book starts with an overview on typical applications of scattered data approximation coming from surface reconstruction fluid structure interaction and the numerical solution of partial differential equations It then leads the reader from basic properties to the current state of research addressing all important issues such as existence uniqueness approximation properties numerical stability and efficient implementation Each chapter ends with a section giving information on the historical background and hints for further reading Complete proofs are included making this perfectly suited for graduate courses on multivariate approximation and it can be used to support courses in computer aided geometric design and meshless methods for partial differential equations

Operators, Inequalities and Approximation Binod Chandra Tripathy, Hemen Dutta, Susanta Kumar Paikray, Bidu Bhusan Jena, 2024-09-18 The book collects chapters on operator theory as well as related approximation results and analytic inequalities It discusses the properties of various types of operators methods for approximating such operators proximity point problems applications of approximation methods in other fields such as engineering and some analytic inequalities It seeks to capture both the pure and applied aspects of the topics discussed Several of the concepts covered in the book are fundamental to many aspects of applied science and engineering The intriguing and novel aspect of the book is that it focuses on foundational aspects of the topics as well as

reasonable application ideas and inputs useful information for practical applications in a variety of other scientific and engineering fields

Series Approximation Methods in Statistics John E. Kolassa, 2013-04-17 This book was originally compiled for a course I taught at the University of Rochester in the fall of 1991 and is intended to give advanced graduate students in statistics an introduction to Edgeworth and saddlepoint approximations and related techniques Many other authors have also written monographs on this subject and so this work is narrowly focused on two areas not recently discussed in theoretical text books These areas are first a rigorous consideration of Edgeworth and saddlepoint expansion limit theorems and second a survey of the more recent developments in the field In presenting expansion limit theorems I have drawn heavily on notation of McCullagh 1987 and on the theorems presented by Feller 1971 on Edgeworth expansions For saddlepoint notation and results I relied most heavily on the many papers of Daniels and a review paper by Reid 1988 Throughout this book I have tried to maintain consistent notation and to present theorems in such a way as to make a few theoretical results useful in as many contexts as possible This was not only in order to present as many results with as few proofs as possible but more importantly to show the interconnections between the various facets of asymptotic theory Special attention is paid to regularity conditions The reasons they are needed and the parts they play in the proofs are both highlighted

Sampling, Approximation, and Signal Analysis Stephen D. Casey, M. Maurice Dodson, Paulo J. S. G. Ferreira, Ahmed Zayed, 2024-01-04 During his long and distinguished career J Rowland Higgins 1935 2020 made a substantial impact on many mathematical fields through his work on sampling theory his deep knowledge of its history and his service to the community This volume is a tribute to his work and legacy featuring chapters written by distinguished mathematicians that explore cutting edge research in sampling approximation signal analysis and other related areas An introductory chapter provides a biography of Higgins that explores his rich and unique life along with a bibliography of his papers a brief history of the SampTA meetings of which he was a Founding Member is also included The remaining articles are grouped into four sections classical sampling theoretical extensions frame theory and applications of sampling theory and explore Higgins contributions to these areas as well as some of the latest developments

Introduction to the Theory of Fourier's Series and Integrals and the Mathematical Theory of the Conduction of Heat Horatio Scott Carslaw, 1906

Topics in Approximation Theory Harold S. Shapiro, 2006-11-15

Walsh Series and Transforms B. Golubov, A. Efimov, V. Skvortsov, 2012-12-06 Et moi si j'avais su comment en revenir One service mathematics has rendered the *je n'y se rais point* aile human race It has put common sense back Jules Verne where it belongs on the topmost shelf next to the dusty canister labelled discarded non sense The series is divergent therefore we may be able to do something with it Eric T Bell

On Heaviside Mathematics is a tool for thought A highly necessary tool in a world where both feedback and non linearities abound Similarly all kinds of parts of mathematics serve as tools for other parts and for other sciences Applying a simple rewriting rule to the quote on the right above one finds such statements as One service topology has rendered mathematical

physics One service logic has rendered computer science One service category theory has rendered mathematics All arguably true And all statements obtainable this way form part of the *raison d'être* of this series Fourier analysis and approximation Paul Leo Butzer,Rolf Joachim Nessel,1971 **Approximation Theory and Applications** Sergei Aliukov,2025-02-04 Approximation Theory and Applications Piecewise Linear and Generalized Functions presents the main provisions of approximation theory and considers existing and new methods for approximating piecewise linear and generalized functions widely used to solve problems related to mathematical modeling of systems processes and phenomena in fields ranging from engineering to economics The widespread use of piecewise linear and generalized functions is explained by the simplicity of their structure However challenges often arise when constructing solutions over the entire domain of these functions requiring the use special mathematical methods to put theory into practice This book first offers a first full foundation in approximation theory as it relates to piecewise linear and generalized functions followed by staged methods to resolve common problems in practice with applications examined across structural mechanics medicine quantum theory signal theory semiconductor theory mechanical engineering heat engineering and other fields Later chapters consider numerical verification of approximation methods and approximation theory as the basis for new macroeconomic theory with impulse and jump characteristics Each chapter includes questions for review and sample problems accompanied by a separate Solutions Manual hosted for instructor access Offers clear comprehensive coverage of approximation theory and applications with full consideration for newly evolved implications of piecewise linear and generalized functions Features practical examples across structural mechanics medicine quantum theory signal theory semiconductor theory mechanical engineering and heat engineering among other fields Includes questions for review sample problems and a separate Solutions Manual hosted for instructor access Considers numerical verification of approximation methods *Approximation Theory and Algorithms for Data Analysis* Armin Iske,2018-12-14 This textbook offers an accessible introduction to the theory and numerics of approximation methods combining classical topics of approximation with recent advances in mathematical signal processing and adopting a constructive approach in which the development of numerical algorithms for data analysis plays an important role The following topics are covered least squares approximation and regularization methods interpolation by algebraic and trigonometric polynomials basic results on best approximations Euclidean approximation Chebyshev approximation asymptotic concepts error estimates and convergence rates signal approximation by Fourier and wavelet methods kernel based multivariate approximation approximation methods in computerized tomography Providing numerous supporting examples graphical illustrations and carefully selected exercises this textbook is suitable for introductory courses seminars and distance learning programs on approximation for undergraduate students

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