Orthogonal Polynomials
and
Special Functions

SIAM Activity Group on Orthogonal Polynomials and Special Functions

★ ★ ★ ★   **Newsletter**   ★ ★ ★ ★
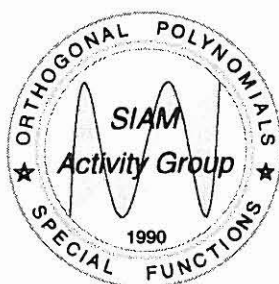
Contents

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The News

We report on our activities at the annual SIAM meeting which took place this July in Philadelphia. Then an article on electromagnetic diffraction serves an as introduction to Problem #7, involving a uniform asymptotic expansion of the incomplete Airy integral. And finally, three solutions to Problem #4 have appeared.

A June 30 e-mail from Walter Van Assche indicated that Springer-Verlag had just published *Thomas Jan Stieltjes,* *Oeuvres Complétes* in two volumes of 564 and 744 pages. Gerrit van Dijk is the editor. We checked with Springer and quote from their announcement: "This is a new, annotated edition of the collected papers of T.J. Stieltjes, published earlier in 1914 (Vol. I) and in 1918 (Vol. 2) by Noordhoff, Groningen, under the title *Oeuvres Complétes* *de Thomas Jan Stieltjes.* Here the impact of Stieltjes' work on modern mathematics, and in particular on the therory of orthogonal polynomials and continued fractions, is described. Stieltjes' claim to have proven the Riemann hypothesis is also discussed. An English translation of Stieltjes' main paper 'Recherches sur les fractions continues' is included in the present book".

Charles Dunkl has been invited to give a talk at a meeting to commemorate the centenary of Cornelius Lanczos, to be held at North Carolina State University in December. For details see the Meetings and Conferences section.

And Hans Haubold has just informed us that his United Nations Office will be moved from New York to the International Centre in Vienna, so he has been very occupied with making the necessary last minute arrangements.

Interesting data on the membership: our February 1993 Membership Directory contains 148 names, of which 84 have e-mail, while 50 members live outside the continental United States—with 22 countries represented. By way of comparison the Fall 1992 Directory listed 115 members.

David R. Masson informs us that he now has e-mail, and his address is masson@math.toronto.edu. This brings the number with e-mail to 85 (and there may still be others) but this amounts to only 57.4% of the membership.

A few additional papers have been received at the ftp site of Waleed Al-Salam. Please refer to the previous issue of this Newsletter for the article on how to access his site, or send an e-mail to waleed@euler.math.ualberta.ca.

In the end section of this edition you will find detailed information on how to submit material to the Newsletter, including a *preamble* for those using LaTeX. The current publication schedule is also given.

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———— *SIAM Activity Group* ————
on
Orthogonal Polynomials and Special Functions

CHARLES DUNKL, *Chair*
GEORGE GASPER, *Vice Chair*
MARTIN E. MULDOON, *Program Director*
TOM KOORNWINDER, *Secretary*

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THE PURPOSE *of the Activity Group is*

—*to promote basic research in orthogonal polynomials and special functions; to further the application of this subject in other parts of mathematics, and in science and industry; and to encourage and support the exchange of information, ideas, and techniques between workers in this field, and other mathematicians and scientists.*

Summary of Philadelphia Minisymposium

Here is a brief report on the the Minisymposium and on other special function activities at the annual SIAM meeting held this year in Philadelphia, July 12-16.

We were pleased to note that the plenary lecture given by David Gottlieb of Brown University, with the title "The Gibbs Phenomenon and Scientific Computing", contained an important application of special functions, namely the use of a Gegenbauer polynomial expansion filter in processing discrete Fourier transforms of shock waves.

At the Group's business meeting an informal discussion was held concerning our proposed contribution to next year's annual SIAM meeting (in San Diego). The working idea now is the theme of asymptotics. More ambitiously, we could aim for two sessions with around eight speakers— perhaps half in the area of asymptotics. Suggestions about a plenary speaker should have been submitted to the SIAM Program Committee (chaired by Barbara Keyfitz, of the University of Houston) in late August. On the other hand, the program for the Minisymposium need not be finalized until December, so we ask that you submit ideas for speakers or otherwise express interest in giving your own talk, by late October.

As for the Minisymposium itself it was well-attended, with Adel Faridani, Peter McCoy and Dennis Stanton presenting their scheduled lectures. Unfortunately, due to unforeseen circumstances Hans Haubold could not attend, but he did send his manuscript to Waleed Al-Salam's ftp site (euler.math.ualberta.ca) for public availability. What follows are three abstracts by the three speakers. We will try to print Haubold's abstract in the next issue.

Quasiregular Sampling and Computed Tomography

by ADEL FARIDANI

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Many applications in signal processing require recovery of a function from discretely sampled values. The classical sampling theorem permits reconstruction of a function (whose Fourier transform has compact support) from its values on a set of equidistant points on the real line $\mathbf{R}$. An important generalization results from replacing $\mathbf{R}$ by an arbitrary locally compact abelian (LCA) group. The sampling set is then a coset of a closed subgroup. Since this requirement on the sampling set is very restrictive, there is great interest in results for more general sets. In this talk we present a theorem for so-called quasiregular sampling sets which are unions of finitely many cosets of a closed subgroup. We then apply this result to sampling the 2-D Radon transform, a problem occurring in computed tomography. Formulating our sampling theorem in the general framework of LCA groups not only permits a simpler and more transparent proof, but also allows a unified treatment of different applications, such as the various sampling geometries used in computed tomography.

Adel Faridani was the starting speaker

In order to derive our sampling theorem we consider the following problem: Let f be defined on an LCA group G. Compute the Fourier transform $\hat{f}(\xi)$ for ξ in a certain compact set K' from a knowledge of f on a finite union of cosets of a subgroup $H \subset G$. The main tool used in the proof is the Poisson summation formula. For $K' = \{0\}$ our problem reduces to numerical integration, and it turns out that our approach has close connections to the method of lattice quadrature rules.

The mathematical problem of computed tomography is to recover a function $f : \mathbf{R}^2 \to \mathbf{R}$ from finitely many of its line integrals. Which line integrals can be measured depends on the particular application. Mathematically most

convenient is the parallel-beam geometry, where the lines are parameterized by an angle φ characterizing their direction, and their signed distance from the origin s. The data function to be sampled is then given by $Rf(\varphi, s) = \int_{x \cdot \theta = s} f(x) dx$ with $\theta = (\cos\varphi, \sin\varphi)$. A different geometry is used in today's hospital scanners, where an x-ray source is moving on a circle with radius r around the patient. This leads to the fan-beam geometry, characterized by the data function $Df(\alpha, \beta) = Rf(\beta + \alpha - \pi/2, r\sin\alpha)$. For fixed β we obtain a 'fan' of lines passing through the source position $(r\cos\beta, r\sin\beta)$. Note that Rf is a function on $G = \mathbf{T} \times \mathbf{R}$ ($\mathbf{T}$ being the torus group) while Df is defined on $\mathbf{T}^2$. Our sampling theorem allows a unified derivation of sampling conditions for both functions. In this talk we suggest new quasiregular sampling sets for the fan-beam geometry and present numerical tests showing that good reconstructions can be obtained using quasiregular parallel-beam sampling.

As general reading on the classical sampling theorem and its many extensions we recommend [1,2]. For recent papers on quasiregular sampling see, e.g., [3] and the article by Cheung in [2, pp.85-119]. Our general sampling theorem is proved in [4]. Research in sampling the Radon transform is summarized in [5, Chap. III]. More recent contributions can be found in [3,6,7].

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Special Functions, Boundary Value Problems and Linear Elliptic Partial Differential Equations

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In signal processing, Shannon's theorem allows the recovery of a bandlimited signal from values sampled at a discrete set of frequencies. We view this concept in the context of elliptic boundary value problems of order ≥ 2 on a bounded domain Ω with $\partial\Omega \in C^\infty$. The idea is to find a sampling theorem for the solution of the BVP.

A procedure is set up for constructing a complete set of orthogonal sampling solutions with properties similar to the "sinc" function in Shannon's theorem. The solution of the BVP is expanded as a series in terms of the sampling solutions and the boundary data sampled at a discrete set of spatial frequencies.

Pete McCoy setting up his transparencies

Equivalent problems are considered. One problem fixes the differential operator and varies the domain; whereas the other fixes the domain and transmutes the differential operator.

Applications follow in a special functions setting for second order axially symmetric problems with entire function coefficients. The Dirichlet data is specified as bandlimited with respect to a boundary integral whose kernel is a Gegenbauer function.

Sampling theorems are developed function theoretically on domains that are starshaped about the origin. In particular the domain is specialized as a sphere or a cardiod of revolution.

Basic Hypergeometric Orthogonal Polynomials and Combinatorics

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Classical orthogonal polynomials such as the Hermite, Laguerre, and Jacobi can be written as hypergeometric series; for example, the Jacobi

$$P_n^{(\alpha,\beta)}(1-2x) = c \; {}_2F_1 \left(\begin{array}{cc} -n & n+\alpha+\beta+1; \quad x \\ & \alpha+1 \end{array} \right).$$

There are several q-analogues of these classical polynomials. In this talk two possible combinatorial avenues of study are given:

1. q is an indeterminate
2. q is a prime power.

If q is an indeterminate, then one can try to find a set of objects S_n, and a weight wt on these objects such that

$$p_n(x) = \sum_{s \in S_n} wt(s).$$

The weight wt must depend upon x, q, and whatever parameters there are in the polynomials. To do integration one must find a set of objects M_n with weights wt such that

$$\mu_n = \int_{-\infty}^{\infty} x^n d\mu(x) = \sum_{m \in M_n} wt(m).$$

This has been been done for sets of q-Hermite, q-Laguerre, and q-Charlier polynomials. One can obtain positivity theorems from this combinatorial viewpoint. Conversely, if the measure is known, new combinatorial theorems can result, for example a new Mahonian statistic for permutations from the q-Laguerre polynomials.

For q being a prime power, we use the fact that discrete orthogonal polynomials are eigenvalues for classical distance regular graphs. The weight function counts the number of vertices in the graph a given distance away. If the vertices of the graph consists of the set of all k-dimensional subspaces of an n-dimensional vector space over a finite field of order q, and edges are between spaces that overlap maximally, the weight is the q-Hahn weight

$$w(j) = \left[\begin{array}{c} k \\ k-j \end{array} \right]_q \left[\begin{array}{c} n-k \\ j \end{array} \right]_q q^{j^2}.$$

Dennis Stanton taking another question

Here are two applications of the polynomials to problems on these graphs. The Erdös-Ko-Rado theorem gives a sharp bound for the independence number of these graphs, and this theorem follows from the explicit form of the polynomials. A dual problem is the the Kneser conjecture (proved by Lovasz) on the chromatic number. It remains open for the q-Johnson scheme. One can also use Diaconis' uniform upper bound lemma, and the exact form of the first eigenvalues to find the cutoff constants for a random walk on the q-Johnson scheme.

And finally, it appears that a product of $r - 1$ affine q-Krawtchouk polynomials with a single q-Hahn polynomial (a polynomial in r variables) is a spherical function for the Gelfand pair of the general linear group over $Z/p^r Z$, with stabilizer on subgroups of type r^k. This generalizes the q-Johnson scheme.

Conference on Hypergroups—Report

George Gasper has compiled this report from the recent conference on hypergroups in Seattle:

There were over 50 mathematicians, from 14 countries, attending the joint AMS–IMS–SIAM summer research conference on "Applications of Hypergroups and Related Measure Algebras." The conference was held August 1–6 in Seattle, at the University of Washington, and it was co-chaired by William C. Connett, Alan L. Schwartz, and Olivier Gebuhrer.

We had over 50 talks presented—on a variety of topics including *Lie hypergroups, probability theory on hypergroups, quantum groups; Gelfand pairs, Fourier and convolution algebras, Banach and C*-algebras, harmonic analysis; Sturm-Liouville operators, hypercomplex systems, orthogonal polynomials in one and several variables,* and *special functions.*

There were talks on *addition formulas, product and linearization formulas,* and *spectral synthesis; Hopf and measure algebras, transmutation operators and inverse spectral problems,* and *random walks on polynomial hypergroups;* plus *graphs, trees,* and *other discrete hypergroups.*

We were fortunate in that, during the first three days, the sky was so clear that on approaching the conference building from the north, each participant had a spectacular view of Mount Rainier (about 60 miles south of the campus). Tuesday afternoon was reserved for sightseeing, visits to downtown Seattle, The Art Museum, Aquarium, Ballard Locks, Pike Place Market, The Science Center, Space Needle, and a ferry ride to Bainbridge Island to explore Winslow, and then dinner at the Saltwater Cafe.

In addition to the co-chairs, the participants included:

Mohamed Akkouchi	Richard A. Askey
Allal Bakali	Yurij Berezansky
Walter Bloom	Houcine Chebli
Charles F. Dunkl	Edward G. Effros
Martin Ehring	Jean Esterle
Pierre Henri Eymard	Ahmed Fitouhi
Gerald B. Folland	John Fournier
Leonard Gallardo	Ramesh Gangolli
George Gasper	Moncef Hamza
Lorna B. Hanes	Herbert Heyer
Robert Jewett	Palle E.T. Jorgensen
Alexander Kalyuzhnyi	Tom H. Koornwinder
Ray Kunze	Christopher Lang
B.M. Levitan	Gregory L. Litvinov
Mohammed Mabrouki	Nour el Houda Mahmoud
Lazhari Nejib	Masatoshi Noumi
Boris P. Osilenker	Gleb Podkolzin
Margit Roesler	Kenneth A. Ross
Rosa Shapiro	Ajit Iqbal Singh
V.S. Sunder	Ryszard Szwarc
Khelifa Trimeche	Leonid Vainerman
Michael Voit	Richard Vrem
K.Ysette Weiss	Norman J. Wildberger
Daming Xu	Zengfu Xu
	Hansmartin Zeuner

A special effort was made to bring colleagues from Morocco and Tunisia to the conference, and to involve both senior and junior researchers in a workshop which initiated cooperative efforts.

The Airy Integral and EM Diffraction

The Electrical Engineering Department at Ohio State has for many years been situated at the frontier of research in electromagnetic (EM) scattering and diffraction. As a prelude to Problem #7, and to emphasize that applied mathematics is alive and healthy, we present a contribution by Evagoras Constantinides and Ron Marhefka.

A Complete Uniform Asymptotic Expansion of the Incomplete Airy function

by E.D. Constantinides and R.J. Marhefka

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The incomplete Airy integral given by[1]

$$I_0(\sigma, \gamma; k) = \int_\gamma^\infty e^{jk(\sigma z + z^3/3)}\, dz \qquad (1)$$

serves as a canonical integral for some sparsely explored diffraction phenomena involving the evaluation of high frequency EM fields near terminated caustics and composite shadow boundaries [1,2]. In equation (1), k is the wavenumber of the propagation medium and it is assumed large. The parameter σ indicates the proximity of the observation point to the caustic whereas the integration endpoint γ indicates the proximity of the observation point to the caustic termination or composite shadow boundary. Both σ and γ are assumed real. Here, we seek a complete asymptotic expansion for I_0 in inverse powers of $k \to \infty$ for the case when the saddle points $z_{1,2} = \pm(-\sigma)^{1/2}$ are real and widely separated ($\sigma \ll -1$).

For an asymptotic expansion of (1) that holds uniformly as the endpoint γ approaches the saddle point z_1, we employ the following transformation [1]:

$$q(z) = \sigma z + z^3/3 = q(z_1) + s^2 = -\frac{2}{3}(-\sigma)^{3/2} + s^2 = \tau(s) \qquad (2)$$

with $\arg(s)$ suitably restricted so that $I_0(\sigma, \gamma; k)$ converges as $s \to \infty$. Hence, employing (2) in (1) we get

$$I_0(\sigma, \gamma; k) = e^{-j\frac{2}{3}k(-\sigma)^{3/2}} \int_\zeta^\infty f_0(s) e^{jks^2}\, ds \qquad (3)$$

with the upper limit taken in the sector $0 \le \arg(s) \le \pi/2$ of the complex s-plane. The quantities ζ and $f_0(s)$ are given by

$$\zeta = \pm \left[\sigma\gamma + \gamma^3/3 + \frac{2}{3}(-\sigma)^{3/2}\right]^{1/2}; \quad \gamma \gtrless (-\sigma)^{1/2} \qquad (4)$$

and

$$f_0(s) = \frac{dz}{ds} = \frac{\tau'(s)}{q'(z)} = \frac{2s}{\sigma + z^2}. \qquad (5)$$

---

[1]Electrical engineers use j for $\sqrt{-1}$, reserving $i = v/r$ for current.

Then, using a method introduced by Lewis [3] along with successive integration by parts the complete asymptotic expansion, or Fresnel integral representation of (3), is as follows:

$$
\begin{aligned}
I_0(\sigma, \gamma; k) = \sum_{n=0}^\infty \Bigg\{ & \frac{(-1)^n}{(2jk)^n} f_n(0)\, e^{-j\frac{2}{3}k(-\sigma)^{3/2}} \int_\zeta^\infty e^{j\Omega s^2}\, ds \\
& + \frac{(-1)^{n+1}}{(2jk)^{n+1}} \left[\frac{f_n(\zeta) - f_n(0)}{\zeta}\right] e^{jk(\sigma\gamma + \gamma^3/3)} \Bigg\} \quad (6)
\end{aligned}
$$

where the function f_n is given by the following recursive relationship:

$$f_n(s) = \frac{s f'_{n-1}(s) - f_{n-1}(s) + f_{n-1}(0)}{s^2}; \quad n = 1, 2, 3, \ldots \qquad (7)$$

In order to compute the terms of the asymptotic series in (6) we need to derive an expression for $f_0(s)$ and its derivatives when $s \approx 0$. Since $f_0(s)$ is regular near zero, it can be expanded in a Taylor series around $s = 0$ by means of Lagrange's theorem. That is, $f_0(s)$ may be written as follows:

$$f_0(s) = \sum_{n=0}^\infty \alpha_n s^n \qquad (8)$$

and this converges uniformly inside a circle of finite radius r centered at $s = 0$. The coefficients α_n are determined using a procedure introduced by Erdélyi [4] that yields:

$$\alpha_n = \frac{(-1)^n \Gamma\left(\frac{3n+1}{2}\right)}{3^n n!\, \Gamma\left(\frac{n+1}{2}\right)(-\sigma)^{(3n+1)/4}}. \qquad (9)$$
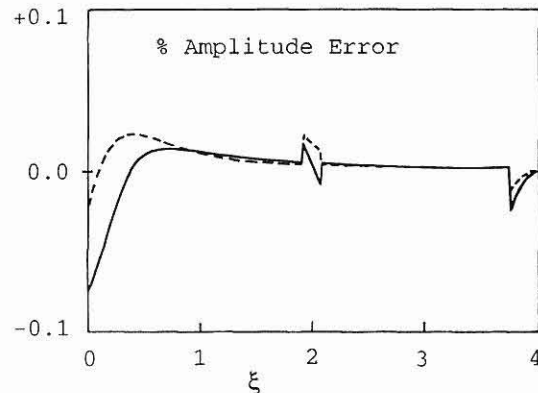

Figure 1: Percent amplitude error of the five term asymptotic series for the incomplete Airy function (solid line) and its derivative (broken line). Results are plotted vs. the parameter ξ with $\beta = -4.0$.

The asymptotic series in (6) was employed in [5] for the evaluation of the incomplete Airy function defined by

$$g_0(\beta, \xi) = \int_\xi^{\infty \exp(j\psi_0)} e^{j(\beta z + z^3/3)} dz, \quad 0 \le \psi_0 \le \pi/3 \qquad (10)$$

when the argument β is large and negative. Figure 1 shows the percentage amplitude error of the asymptotic result using five terms of the asymptotic series. The reference data

was obtained using a Taylor series representation for g_0 derived in [5]. The error results for both the function (solid line) and its derivative (broken line) are plotted vs. the parameter ξ, with $\beta = -4.0$. The asymptotic result shows excellent agreement with the series solution, exhibiting a maximum error of only 0.075%.

The computation of higher order phase integrals, such as the incomplete Pearcey function given by

$$P_e(\alpha, \beta, \gamma; k) = \int_\gamma^\infty e^{j(\alpha z + \beta z^2 + z^4/4)}\, dz \qquad (11)$$

is also of great interest. We note that several expansions for the *complete* Pearcey integral exist in the literature [6,7,8]. Similar expansions for the incomplete integral can be found but they are expected to be more challenging.

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Two Maple Packages

What follows is a report on two Maple packages for doing symbolic manipulation on a computer. Both are available by ftp and we accordingly make the usual disclaimer: there is no guarantee or warranty.

First there is a contribution from Doron Zeilberger on dealing with hypergeometric function identities and related problems. It is available by ftp from the site:

math.temple.edu

in the directory pub/zeilberger/programs.

Second there is a revised version of John Stembridge's symmetric function package called SF 2. Here are a few comments taken from his announcement:

SF 2 is an improvement over SF 1 in several respects. It has better speed and space-efficiency, more functions, and better documentation. SF 1 can do any computation of the type one finds in the first chapter of Macdonald's book on symmetric functions but SF 2 can do more. Perhaps the most interesting new feature in SF 2 is an enhanced ability to manipulate sophisticated symmetric functions, such as Hall-Littlewood functions.

Here are instructions for getting a copy of SF 2.

1) 'cd' to the directory where you plan to store the package. (e.g., /usr/local/maple/package)

2) Issue the UNIX command

ftp ftp.math.lsa.umich.edu

(currently equivalent to ftp 141.211.64.51)

Use "anonymous" as your username and your name as the password. After you get the "ftp>" prompt, issue the following ftp commands:

```
cd pub/jrs
binary
get SF.tar.Z
bye
```

3) Back on your UNIX machine issue the commands

```
uncompress SF.tar.Z
tar -xvf SF.tar
```

4) Follow the instructions in the file READ_ME.SF to install the package.

SF 2 requires Maple V (Release 1 or 2) running in a UNIX environment. Eventually SF 2 will probably be added to the Maple Share Library (SF 1 is there already). But until that happens, you will need a UNIX machine on the Internet to acquire and unpack the software.

John has also made some minor cosmetic changes in his other packages (posets, coxeter, and weyl) to make them more compatible with Maple V, Release 2.

Meetings and Conferences

Some of these items have appeared in previous editions so you may be reading them here for the third time.

1. A conference on "Nonlinear Numerical Methods and Rational Approximation" will be held at the University of Antwerp from September 5 to 11, 1993. Registration will cover housing, participation, and a copy of the conference proceedings—which will be similar to the 1987 proceedings. Special attention will be paid to housing and to social events for the participants.

The emphasis will be on Padé approximation, rational interpolation, rational approximation, continued fractions, and orthogonal polynomials. Each of these topics will be introduced by a one hour survey lecture. Also welcome are contributions on multivariate or multidimensional problems, error analysis, software development, and applications. Participants are invited to present a 20 minute research talk.

The invited speakers will be A. Gonchar (Moscow), M. Gutknecht (Zürich), W.B. Jones (Boulder, USA), D. Lubinsky (Witwatersrand, South Africa), and E. Saff (Tampa, USA).

For more information contact the organizer, who is

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2. "Symbolic Computation in Combinatorics" is the title of a workshop to be held from September 21 to 24, 1993 at the Mathematical Sciences Institute of Cornell University in Ithaca, N.Y. Lectures will be given at the Center for Symbolic Methods in Algorithmic Mathematics, often called ACSyAM. This center is supported by the U.S. Army Research Office.

The focus of the workshop will be on the role of computer algebra in solving problems concerning symbolic manipulation of combinatorial formulae, and on the formal treatment of analytical problems in combinatorics. For example, q-binomial sums, q-hypergeometric series, and recurrences will be considered. The intended scope also includes nontrivial applications as well as new algorithms, systems aspects, and demonstrations. As for the main speakers, G.E. Andrews will speak on "AXIOM and the Borwein Conjecture", P. Flajolet will give a talk on "Statistical Combinatorics", and D. Zeilberger will talk about "The Holonomic Paradigm and beyond".

The workshop is being co-organized by

P. Paule   ppaule@risc.uni-linz.ac.at,   and
V. Strehl   strehl@informatik.uni-erlangen.de

3. An "International Joint Symposium on Special Functions and Artificial Intelligence" will be held in Torino Italy on October 14-15, 1993. The Symposium is dedicated to Luigi Gatteschi and Francesco Lerda on the occasion of their seventieth birthdays.

The Symposium is being organized by Dipartimento di Matematica dell'Universitá di Torino, with financial support from various Italian agencies. According to the brochure now in circulation, the purpose of the Symposium is to bring together well-known researchers in special functions and in artificial intelligence. Two parallel sessions are planned, with 12 speakers for each topic. From our own activity group Francisco Marcellan, André Ronveaux, and Jet Wimp are scheduled to speak.

The organizers are G. Allasia and C. Dagnino Chiesa of the Dipartimento di Matematica, Universitá di Torino. For information please contact

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4. Walter Van Assche has forwarded this information about an October meeting in Leuven:

The Belgian Contact Group on "Special Functions and Their Applications" is organizing a meeting on Friday, October 22, 1993 at the Katholieke Universiteit, Leuven.

The invited speakers will be Mourad E.H. Ismail of the University of South Florida (Tampa, FL, USA) who will present a talk on "q-beta integrals and biorthogonal rational functions"; Gérard Letac of the Université Paul Sabatier (Toulouse, France) who will talk about "The $2d+4$ types of Meixner polynomials in R^d"; and Christian Berg of the University of Copenhagen, Denmark, who will speak about "The Nevanlinna parametrization for some indeterminate Stieltjes moment problems associated with birth and death processes".

Besides these invited talks there will be time reserved for the shorter communications. A detailed program and directions on how to get to Leuven will be mailed in early October to anyone responding to this announcement.

We hope to see you in Leuven!

André Ronveaux	Walter Van Assche
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or Fax: (32) 16 293 545.

(André is President of the Contact Group and Walter is the Secretary—Ed.)

5. North Carolina State University will host a conference in Raleigh from December 12–17, 1993 to celebrate the 100th anniversary of Cornelius Lanczos (1893-1974). The conference will reflect the wide interests of Lanczos— in computational mathematics, theoretical physics, and in astrophysics. The program will include 25 invited plenary speakers and 25 minisymposia, approximately. Contact

> Lanczos International Centenary Conference
> Attn: Sheehan /Heggie
> NCSU/OCE&PD, Box 7401
> Raleigh, NC 27695 lanczos@math.ncsu.edu

6. A session on the topic of special functions will be held during the March 25-26, 1994 meeting of the AMS in Manhattan, Kansas. Anyone who might be interested in presenting a paper at this meeting should please contact

> Robert Gustafson
> Department of Mathematics
> Texas A&M University
> College Station, TX 77843,
> Tel: (409) 764-8933 and (409) 845-3950
> Fax: (409) 845-6028 rgustaf@math.tamu.edu

7. The 100th anniversary of T.J. Stieltjes' premature death will be commemorated in 1994-95. A number of activities are planned in Leiden, and also in Toulouse.

First of all, in April 1994 the Congress of Wiskundig Genootschap (The Dutch Mathematical Society) will be held in Leiden, where Richard Askey will give the Stieltjes Lecture. Contact:

> Prof. Gerrit van Dijk
> Rijksuniversiteit Leiden
> Afdeling Wiskunde en Informatica
> P.O. Box 9512
> 2300 RA Leiden, The Netherlands

Then in Toulouse there will be a colloquium in the Spring of 1995. The focus will be on continued fractions and moment problems, orthogonal polynomials, Laplace transforms, the Riemann hypothesis, and other topics. This will have a somewhat historical character. There will also be an emphasis on the work of Stieltjes in both the graduate and undergraduate seminars. Contact:

> Prof. J.-B. Hiriart-Urruty
> Groupe d'Histoire des Mathématiques
> de l'Université Paul Sabatier
> 118, Route de Narbonne
> 31062 Toulouse, France

The classical focus will be continued by Gerrit van Dijk who is preparing an article on the life and work of Stieltjes for The Mathematical Intelligencer.

Problems

2. Is it true that

$$x^2 t^x \, {}_2F_1(x+1,\, x+1;\, 2;\, 1-t)$$

is a convex function of x whenever $-\infty < x < \infty$ and $0 < t < 1$?

Submitted by George Gasper, August 19, 1992.
(g-gasper@nwu.edu)

3. The following Toeplitz matrix arises in several applications. Define for $i \neq j$

$$A_{ij}(\alpha) = \frac{\sin \alpha \pi (i-j)}{\pi(i-j)},$$

and set $A_{ii} = \alpha$. Conjecture: the matrix

$$M = (I - A)^{-1}$$

has positive entries. A proof is known for $0 < \alpha \le 1/2$. Can one extend this to $0 < \alpha < 1$?

Submitted by Alberto Grünbaum, November 3, 1992.
(grunbaum@math.berkeley.edu)

4. Prove that

$$\sum_{n=0}^{\infty} \frac{(-)^n (6n + 1/2)!}{\sqrt{\pi}\,(6n+1)!} = \frac{\sin \frac{\pi}{8}}{3\sqrt[4]{2}} + \sqrt{\frac{\sqrt{6} - \sqrt{3} - \sqrt{2} + 2}{18}}.$$

Submitted by R. William Gosper, May 10, 1993.
(Tel: (415) 948-2149   Fax: (415) 948-2443)

5. The result of Problem #4 can be generalized to

$$
\begin{aligned}
S_m &= \sum_{n=0}^{\infty} \frac{(-1)^n (mn + 1/2)!}{\sqrt{\pi}\,(mn+1)!} \\
&= \frac{1}{m} \sum_{k=0}^{m-1} \frac{\sin\left(5(2k+1)\pi/(4m) + \pi/4\right)}{[2\sin((2k+1)\pi/(2m))]^{1/2}}
\end{aligned}
$$

valid for integral $m \ge 2$.

Submitted by J. Boersma and P.J. de Doelder, July 12, 1993.

(wstanal@win.tue.nl)

6. For nonnegative integral n, let

$$\phi_n(x) = P_n(1 - 2x) = {}_2F_1(-n, n+1; 1; x).$$

Evaluate the integral

$$\Delta_{m,n}(\alpha) = \int_0^1 \phi_n(x) \int_0^1 \frac{\phi_m(t)}{|x-t|^\alpha}\, dt\, dx, \quad (\alpha < 1)$$

as a rational function of α.

Submitted by Barbara S. Bertram and Otto G. Ruehr, August 3, 1993.

(bertram@math.mtu.edu   otto@math.mtu.edu)

7. The incomplete Airy integral given by

$$I_0(\sigma, \gamma; k) = \int_\gamma^\infty e^{jk(\sigma z + z^3/3)}\, dz \qquad (1)$$

serves as a canonical integral for some sparsely explored diffraction phenomena involving the evaluation of high frequency EM fields near terminated caustics and composite shadow boundaries. In equation (1), k is the wavenumber of the propagation medium and is assumed to be the large parameter. Both the parameters σ and γ are real.

The desired task is to derive a complete asymptotic expansion for I_0 in inverse powers of $k \to \infty$ for the case when the saddle points of the integrand satisfying

$$
\begin{aligned}
z^2 + \sigma &= 0 & (2) \\
z_{1,2} &= \pm(-\sigma)^{1/2} & (3)
\end{aligned}
$$

are real and widely separated ($\sigma \ll -1$). The asymptotic expansion should be of the form

$$I_0(\sigma, \gamma; k) \sim \sum_{n=0}^{\infty} k^{-n} f(\sigma, \gamma, n) \qquad (4)$$

in which $f(\sigma, \gamma, n)$ is expressed in terms of known and easily computed functions. The asymptotic expansion in (4) should also hold uniformly as the endpoint γ approaches, or coincides with, one of the saddle points.

Submitted by E.D. Constantinides and R.J. Marhefka, August 11, 1993.

(evagoras@tiger.eng.ohio-state.edu)
(rjm@tiger.eng.ohio-state.edu)

(See their article on EM diffraction, this issue—Ed.)

———————

A Correction

In the last issue we reprinted a short bio of Ramanujan which concluded with the statement *"A conjecture made by Ramanujan in 1916 was proved only in the year 1974, by the French Mathematician Deligne using very sophisticated methods of Algebraic Geometry."* Actually, Pierre Deligne was born in Brussels on October 3, 1944, and he studied at the University of Brussels, therefore he is Belgian and not French. He studied with Jacques Tits, Alexandre Grothendieck, and Jean-Pierre Serre. Deligne won the Fields medal in 1978.

Thanks to our Belgian colleagues for pointing this out. We have also passed the information on to our friends in Madras, from whom the bio on Ramanujan was copied. We regret the error—for which we take responsibility.

———————

Solutions to Problem #4

Three solutions were submitted and we have decided to print them all, in the order received.

Bill Gosper had a disc crash, unfortunately lasting for several weeks, leaving him stranded without his Macsyma, his tables or TEX. That caused him to rummage through ABRAMOWITZ and STEGUN where he found that a linear combination of 15.1.21 and 15.1.31 led to our problem #4, which Mizan referred to as rather elementary. Now that the disc is up and running, Bill promises something rather substantial to keep Mizan busy.

Not surprisingly Mizan uses q-series, while the other two solutions, one by Boersma and de Doelder, and the other by Otto Ruehr, rely on the beta integral.

Solution to Problem #4
by J. BOERSMA and P.J. DE DOELDER

Department of Mathematics
Eindhoven University of Technology
5600 MB Eindhoven, The Netherlands

Let the sum of the series be denoted by S_6. By use of the beta integral

$$\frac{(6n+1/2)!\sqrt{\pi}}{(6n+1)!} = \int_0^1 t^{6n+1/2}(1-t)^{-1/2}\,dt$$

we establish the integral representation

$$S_6 = \frac{1}{\pi}\int_0^1 \frac{t^{1/2}(1-t)^{-1/2}}{1+t^6}\,dt.$$

Through the substitution $t = 1/(z^2+1)$ the integral transforms into

$$S_6 = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{(z^2+1)^4}{(z^2+1)^6+1}\,dz$$

which is evaluated by contour integration in the complex z-plane. In the upper half-plane $\operatorname{Im} z > 0$ the integrand has simple poles at $z = z_k$ and $z = -\overline{z}_k$, $k = 0, 1, 2$, where z_k is determined by

$$z_k^2 + 1 = \exp\left((2k+1)\pi i/6\right), \quad \operatorname{Im} z_k > 0.$$

Thus we have

$$z_k = \exp\left((2k+7)\pi i/24\right)[2\sin\left((2k+1)\pi/12\right)]^{1/2}.$$

The sum of the residues of the integrand at $z = z_k$ and $z = -\overline{z}_k$ is found to be

$$\frac{1}{12z_k(z_k^2+1)} - \frac{1}{12\overline{z}_k(\overline{z}_k^2+1)} = \frac{-i\sin\left((10k+11)\pi/24\right)}{6[2\sin\left((2k+1)\pi/12\right)]^{1/2}}$$

and by the residue theorem we obtain

$$S_6 = \frac{1}{3}\sum_{k=0}^2 \frac{\sin\left((10k+11)\pi/24\right)}{[2\sin\left((2k+1)\pi/12\right)]^{1/2}}.$$

The latter sum can be simplified to

$$S_6 = \frac{1}{6}\left[\sqrt{\cot\left(\pi/24\right)} + \sqrt{\tan\left(\pi/8\right)} - \sqrt{\cot\left(5\pi/24\right)}\right] \quad (1)$$

which is now expressed in terms of trigonometric functions. By substitution of the known values

$$\cot\left(\pi/24\right) = \frac{1+\cos\left(\pi/12\right)}{\sin\left(\pi/12\right)} = (\sqrt{2}+1)(\sqrt{3}+\sqrt{2})$$

$$\tan\left(\pi/8\right) = \frac{1-\cos\left(\pi/4\right)}{\sin\left(\pi/4\right)} = \sqrt{2}-1$$

$$\cot\left(5\pi/24\right) = \frac{1+\cos\left(5\pi/12\right)}{\sin\left(5\pi/12\right)} = (\sqrt{2}-1)(\sqrt{3}+\sqrt{2})$$

we are led to the final result

$$S_6 = \frac{1}{6}(\sqrt{2}-1)^{1/2}[1+\sqrt{2}(\sqrt{3}+\sqrt{2})^{1/2}]. \quad (2)$$

As a check, the numerical evaluation of both (1) and (2) yields $S_6 = 0.3763408\ldots$. Observe that

$$\sin\left(\pi/8\right) = 2^{-3/4}(\sqrt{2}-1)^{1/2}$$

in the result to be proved, so there is agreement with (2).

Remarks.

1) Note that S_6 can be expressed as a generalized hypergeometric function ${}_6F_5$ with argument -1:

$$S_6 = \frac{1}{2}\,{}_6F_5\left[\begin{array}{cccccc} \frac{3}{12}, & \frac{5}{12}, & \frac{7}{12}, & \frac{9}{12}, & \frac{11}{12}, & \frac{13}{12}; \quad -1 \\[4pt] \frac{2}{6}, & \frac{3}{6}, & \frac{4}{6}, & \frac{5}{6}, & \frac{7}{6} \end{array}\right].$$

2) The result of this problem can be generalized to

$$\begin{aligned} S_m &= \sum_{n=0}^{\infty} \frac{(-1)^n (mn+1/2)!}{\sqrt{\pi}\,(mn+1)!} \\ &= \frac{1}{m}\sum_{k=0}^{m-1} \frac{\sin\left(5(2k+1)\pi/(4m)+\pi/4\right)}{[2\sin\left((2k+1)\pi/(2m)\right)]^{1/2}} \end{aligned}$$

valid for integral $m \geq 2$.   (Received July 12, 1993)

<div style="text-align:center">

Solution to Problem #4
by Mizan Rahman

</div>

Department of Mathematics and Statistics
Carleton University, Ottawa, Ontario K1S 5B6

Gosper's identity

$$\sum_{n=0}^{\infty}(-1)^n\frac{(6n+\frac{1}{2})!}{\sqrt{\pi}(6n+1)!}=\frac{\sin\frac{\pi}{8}}{3\sqrt[4]{2}}+\sqrt{\frac{\sqrt{6}-\sqrt{3}-\sqrt{2}+2}{18}}\quad(1)$$

is rather elementary so I will first give a q-extension:

$$\sum_{n=-\infty}^{\infty}\frac{(aq^{6n+2};q)_\infty}{(bq^{6n+3/2};q)_\infty}(q^\alpha e^{\pi i/6})^{6n}=\frac{(q,aq^{1/2}/b;q)_\infty}{6(bq^{3/2},q^{-1/2}/b;q)_\infty}\times$$

$$\times\left[\frac{(bq^{\alpha+3/2}e^{\pi i/6},\,q^{-\alpha-1/2}e^{-\pi i/6}/b;q)_\infty}{(q^\alpha e^{\pi i/6},\,aq^{1/2-\alpha}e^{-\pi i/6}/b;q)_\infty}\right.$$

$$+\frac{(-bq^{\alpha+3/2}e^{-\pi i/6},\,-q^{-\alpha-1/2}e^{\pi i/6}/b;q)_\infty}{(-q^\alpha e^{-\pi i/6},\,-aq^{1/2-\alpha}e^{-\pi i/6}/b;q)_\infty}$$

$$\left.+\frac{(ibq^{\alpha+3/2},\,-iq^{-\alpha-1/2}/b;q)_\infty}{(iq^\alpha,\,-aiq^{1/2-\alpha}/b;q)_\infty}\right]+(c.c.)\quad(2)$$

where $(c.c.)$ stands for complex conjugate of the preceding expression, and it is assumed that q,a,b,α are real, $0<q<1$ and $\left|\frac{a}{b}\right|q^{1/2}<q^\alpha<1$. This follows directly from Ramanujan's $_1\psi_1$ summation formula by observing that the bilateral series on the left side of (2) is equivalent to

$$\frac{(aq^2;q)_\infty}{(bq^{3/2};q)_\infty}\sum_{n=-\infty}^{\infty}\frac{(bq^{3/2};q)_n}{(aq^2;q)_n}(q^\alpha e^{\pi i/6})^n\sum_{k=0}^{5}p^{kn}$$

where $p=e^{\pi i/3}$. See Gasper and Rahman's book *Basic Hypergeometric Series* for various summation formulas and notations.

For the special case $a=b=1$, $0<\alpha<1/2$ we have

$$\sum_{n=-\infty}^{\infty}\frac{(q^{3/2};q)_{6n}}{(q^2;q)_{6n}}q^{6\alpha n}(-1)^n=-\frac{1+q^{1/2}}{6q^{1/2}}\times$$

$$\times\left[(1+iq^{-\alpha-1/2})\frac{(iq^{\alpha+3/2};q)_\infty}{(iq^\alpha;q)_\infty}\right.$$

$$+(1+q^{-\alpha-1/2}e^{\pi i/6})\frac{(-q^{\alpha+3/2}e^{-\pi i/6};q)_\infty}{(-q^\alpha e^{-\pi i/6};q)_\infty}$$

$$\left.+(1-q^{-\alpha-1/2}e^{-\pi i/6})\frac{(q^{\alpha+3/2}e^{\pi i/6};q)_\infty}{(q^\alpha e^{\pi i/6};q)_\infty}\right]$$

$$+(c.c.)\quad=S(q),\quad\text{say.}\quad(3)$$

Using the limit of the q-binomial formula we get

$$\lim_{q\to1-}S(q)=$$

$$=\frac{1}{3}\left[\frac{e^{-\pi i/6}}{\sqrt{1-e^{\pi i/6}}}-\frac{e^{\pi i/6}}{\sqrt{1+e^{-\pi i/6}}}-\frac{i}{\sqrt{1-i}}\right]+(c.c.).\quad(4)$$

However

$$\frac{-i}{\sqrt{1-i}}+(c.c.)=\frac{-2\cos\left[(\pi/2)+(\pi/8)\right]}{2^{1/4}}=\frac{2\sin\left(\pi/8\right)}{2^{1/4}}\quad(5)$$

and

$$\frac{e^{-\pi i/6}}{\sqrt{1-e^{\pi i/6}}}-\frac{e^{\pi i/6}}{\sqrt{1+e^{-\pi i/6}}}+(c.c.)=\quad(6)$$

$$=\frac{2\cos\left(\pi/24\right)}{\sqrt{2}\sin\left(\pi/12\right)}-\frac{2\cos\left(5\pi/24\right)}{\sqrt{2}\cos\left(\pi/12\right)}$$

$$=2\left[\sqrt{2}\cos\frac{\pi}{24}\sqrt{\cos\frac{\pi}{12}}-\sqrt{\sin\frac{\pi}{12}}\left(\sin\frac{\pi}{24}+\cos\frac{\pi}{24}\right)\right]$$

$$=2\sqrt{P},\qquad\text{say.}$$

Denoting $\theta=\pi/24$ we have

$$P=2\cos^2\theta\cos2\theta+\sin2\theta(\cos\theta+\sin\theta)^2$$

$$-\sqrt{2}\cos\theta(\sin\theta+\cos\theta)$$

$$=1+\cos2\theta+\sin2\theta-\sqrt{2}\left(\cos^2\theta+\cos\theta\sin\theta\right)$$

$$=\left(1-\frac{1}{\sqrt{2}}\right)(1+\cos2\theta+\sin2\theta).\quad(7)$$

Now

$$1+cos(\pi/12)+\sin\left(\pi/12\right)=$$

$$=\frac{2+\sqrt{2+\sqrt{3}}+\sqrt{2-\sqrt{3}}}{2}$$

$$=\frac{1}{2}\left[2+\frac{3-\sqrt{3}}{\sqrt{2-\sqrt{3}}}\right]=\frac{1}{2}\left[2+\frac{\sqrt{3}\left(\sqrt{3}-1\right)}{\sqrt{2-\sqrt{3}}}\right]$$

$$=\frac{1}{2}\left(2+\sqrt{6}\right).\quad(8)$$

Using $(5)-(8)$ in (4) and the formula

$$\lim_{q\to1-}\frac{(q;q)_\infty}{(q^{1/2};q)_\infty}(1-q)^{1/2}=\Gamma(1/2)=\sqrt{\pi}\quad(9)$$

we derive (1).   (Received July 12, 1993)

Solution to Problem #4
by OTTO G. RUEHR

Department of Mathematical Sciences
Michigan Technological University
Houghton, MI 49931

Consider a more general problem: evaluate $f_p(x)$, where

$$f_p(x) = \sum_{n \geq 0} \frac{(-x^{2p})^n (2pn + \frac{1}{2})!}{\sqrt{\pi}(2pn + 1)!}.$$

Represent the summand as a beta integral, and sum to get

$$f_p(x) = \frac{1}{\pi} \int_0^1 \sqrt{\frac{t}{1-t}} \frac{dt}{1 + (xt)^{2p}}.$$

By a partial fraction expansion one obtains

$$f_p(x) = \frac{1}{2p} \sum_{s=1}^{p} g(x^2 r_s)$$

where $r_s = e^{i\pi(2s+1)/p}$ and

$$g(z) = \frac{2}{\pi} \int_0^1 \sqrt{\frac{t}{1-t}} \frac{dt}{1 - zt^2}$$
$$= {}_2F_1 \left[\frac{3}{4}, \frac{5}{4}; \frac{3}{2}; z \right] = \sqrt{\frac{2 - 2\sqrt{1-z}}{z(1-z)}}.$$

The last step employs one of the quadratic transformations of Gauss, namely

$${}_2F_1 \left(a, a + \frac{1}{2}; c; \frac{4y}{(1+y)^2} \right) = (1+y)^{2a} {}_2F_1(2a, 2a+1-c; c; y).$$

with $a = \frac{3}{4}$, $c = \frac{3}{2}$.

For $p = 3$ we find

$$r_1 = -1, \quad r_2 = e^{i\pi/3}, \quad r_3 = e^{-i\pi/3}$$

and

$$f_3(x) = \sqrt{\frac{\sqrt{1 + x^2} - 1}{18x^2(1 + x^2)}} +$$

$$\sqrt{\frac{1 + x^2 - x^2\sqrt{v} - (1 - x^2)\sqrt{v - 3} + u\sqrt{w} - u\sqrt{w - 4x^2}}{18x^2u^2}}$$

where $u^2 = 1 - x^2 + x^4$, $v = 2u + 2 - x^2$, and $w = v + 3x^2$. Appropriately, for $x = 1$ this reduces to Gosper's result.

(Received August 4, 1993)

How to Submit Material for the Newsletter

Like most newsletters, this one relies on input from the members it is supposed to serve.

Here is the publication schedule. Material received on or before a *Draft #1* date can be included in that particular edition. Material received after such a date will have to be considered for a later edition.

Edition	*Draft #*1	*Mailing* $\approx$
Fall	August 10	September 1
Winter	November 10	December 1
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Please send your Newsletter contributions to the Editor

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The preferred mode is a LaTeX file sent by e-mail. This should be followed by a hard copy which is necessary if you have graphs or drawings. Note that the column width is exactly 3.5 inches while the font is the default `\normalsize` (`cmr10`); also these constraints may tax your patience when typesetting the longer formulas. Here is the LaTeX *preamble* you will need when setting up your manuscript.

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You may also send your contributions to the Chair of the Activity Group

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The **Newsletter** is a quarterly publication of the *SIAM Activity Group on Orthogonal Polynomials and Special Functions*. The Editorial Committee consists of Charles Dunkl, George Gasper, and Eugene Tomer.

To join the group and thereby receive the Newsletter, please contact

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NICHOLAS J. HIGHAM

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SIAM

Optimization Software Guide

Jorge J. Moré and Stephen J. Wright
Frontiers in Applied Mathematics 14

Available November 1993
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Developments in optimization theory, including emphasis on large problems and on interior-point methods for linear programming, have begun to appear in production software. Here is a reference tool that includes discussions of these areas and names software packages that incorporate the results of theoretical research. After an introduction to the major problem areas in optimization and an outline of the algorithms used to solve them, a data sheet is presented for each of the 75 software packages and libraries in the authors' survey. These include information on how to use the packages, what they can handle, and where to find them.

Standard optimization paradigms are addressed — linear, quadratic, and nonlinear programming; network optimization; unconstrained and bound-constrained optimization; least-squares problems; nonlinear equations; and integer programming. The most practical algorithms for the major fields of numerical optimization are outlined, and the software packages in which they are implemented are described.

This format will aid the non-optimization specialist in deciding what kind of optimization problem they need to solve, what algorithms are appropriate, and how to obtain the software that implements those algorithms.

Contents

Preface; Part I: Overview of Algorithms; Chapter 1. Optimization Problems and Software; Chapter 2. Unconstrained Optimization; Chapter 3. Nonlinear Least Squares; Chapter 4. Nonlinear Equations; Chapter 5. Linear Programming; Chapter 6. Quadratic Programming; Chapter 7. Bound-Constrained Optimization; Chapter 8. Constrained Optimization; Chapter 9. Network Optimization; Chapter 10. Integer Programming; Chapter 11. Miscellaneous Optimization Problems; **Part II: Software Packages:** AMPL; BQPD; BT; BTN; CNM; CONOPT; CONSOL-OPTCAD; CPLEX; C-WHIZ; DFNLP; DOC; DOT; FortLP; FSQP; GAMS; GAUSS; GENESIS; GENOS; GINO; GRG2; HOMPACK; IMSL Fortran and C Library; LAMPS; LANCELOT; LBFGS; LINDO; LNOS; LINGO; LPsolver; LSGRG2; LSNNO; LSSOL; M1QN2 and M1QN3; MATLAB; MINOS; MINPACK-1; MIPIII; MODULOPT; NAG C library; NAG Fortran Library; NETFLOW; NETSOLVE; NITSOL; NLPE; NLPQL; NLPQLB; NLSFIT; NLSSOL; NLPSPR; NPSOL; OB1; ODRPACK; OPSYC; OptiA; OPTIMA Library; OPTPACK; OSL; PC-PROG; PITCON; PORT 3; PROC NLP; Q01SUBS; QAPP; QPOPT; SQP; SPEAKEASY; TENMIN; TENSOLVE; TNPACK; TN/TNBC; UNCMIN; VE08; VE10; VIG; VIMDA; **What's Best!**; Bibliography.

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