

Who invented the great numerical algorithms?

Nick Trefethen, starting about 2004



A discussion over coffee.
Ivory tower or coal face?

SOME MAJOR DEVELOPMENTS IN SCIENTIFIC COMPUTING

(29 of them)

Before 1940

Newton's method
least-squares fitting
Gaussian elimination
Gauss quadrature
Adams formulae
Runge-Kutta formulae
finite differences

1940-1970

floating-point arithmetic
splines
Monte Carlo methods
simplex algorithm
conjugate gradients & Lanczos
Fortran
stiff ODE solvers
finite elements

orthogonal linear algebra
QR algorithm
Fast Fourier Transform
quasi-Newton iterations

1970-2000

preconditioning
spectral methods
MATLAB
multigrid methods
IEEE arithmetic
nonsymmetric Krylov iterations
interior point methods
fast multipole methods
wavelets
automatic differentiation

Before 1940

Newton's Method for nonlinear eqs.

Heron, al-Tusi 12c, Al Kashi 15c, Viète 1600, Briggs 1633...

Isaac Newton 1642-1727

Mathematician and physicist

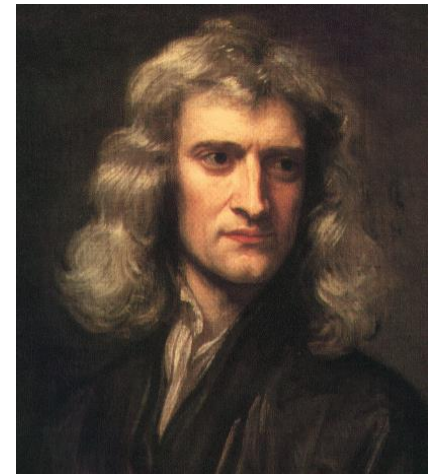
Trinity College, Cambridge, 1661-1696

(BA 1665, Fellow 1667,

Lucasian Professor of Mathematics 1669)

De analysi per aequationes numero terminorum infinitas **1669** (published 1711)

After 1696, Master of the Mint



Joseph Raphson 1648-1715

Mathematician at Jesus College, Cambridge

Analysis Aequationum universalis **1690**

Raphson's formulation was better than Newton's ("plus simple" - Lagrange 1798)

FRS 1691, M.A. 1692

Supporter of Newton in the calculus wars — *History of Fluxions*, 1715

Thomas Simpson 1710-1761

1740: *Essays on Several Curious and Useful Subjects...*

1743-1761: Royal Military Academy, Woolwich

Important! — first to treat non-polynomial equations, first to treat systems of eqs.

Least-squares fitting

Carl Friedrich Gauss 1777-1855

Mathematics, astronomy, geodesy, magnetism

1792-1795: Braunschweig Collegium Carolinum

1795, but not published until 1809

(→ big fight with Legendre)

(During this time as a teenager in Braunschweig Gauss also discovered the binomial theorem, quadratic reciprocity, arithmetic-geometric mean,...)

1807-1855: University of Göttingen



Adrien-Marie Legendre 1752-1833

1791-1833: Académie des Sciences, Paris

1805 “Sur la méthode des moindres carrés”
applications to orbits of comets



Gaussian elimination for linear systems of eqs.

Liu Hui c. 220 – c. 280

Chinese mathematician discusses already long-established elimination method in commentaries on *The Nine Chapters on the Mathematical Art* **263 AD**

Cardano (1554), Peletier (1554), Buteo (1560), Gosselin (1577), Newton (1720),...

Joseph Lagrange 1736-1813

Symmetric quadratic forms **1759**

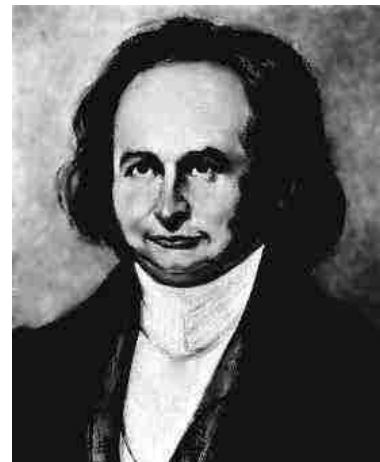
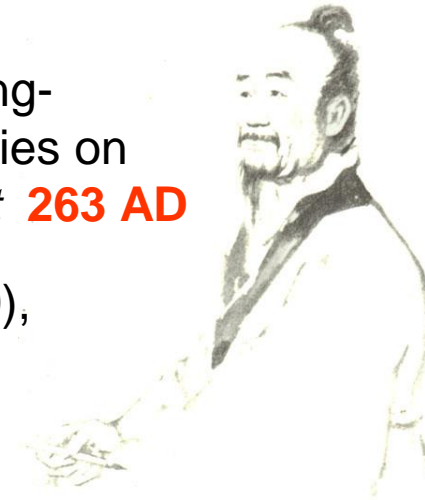
Carl Friedrich Gauss 1777-1855

Symmetric systems, normal eqs. **1809**

Carl Gustaf Jacob Jacobi 1804-1851

1826-1844: U. of Königsberg

General systems **1857** (posthumous)



Gauss quadrature for numerical integration

Carl Friedrich Gauss 1777-1855

“Methodus nova integralium valores per approximationem
inveniendi”, *Comment. Soc. Reg. Sient. Götting. Recent.* **1814**



Gauss did it by continued fractions and hypergeometric functions. Today's more familiar interpretation via orthogonal polynomials was developed by **Jacobi** (1804-1851) in **1826**.



Adams formulae for ODEs

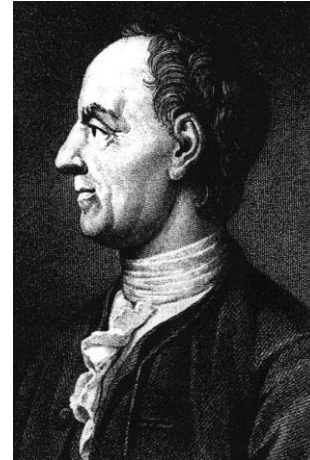
Leonhard Euler 1707-1783

1727-1741: St. Petersburg Academy

1768: *Institutiones Calculi Integralis*

1741-1766: Berlin Academy

1766-1783: St. Petersburg Academy



John Couch Adams 1819-1892

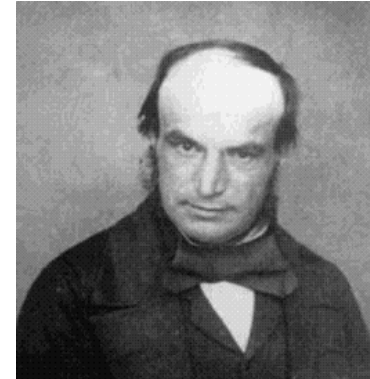
astronomer and mathematician; predicted existence of Neptune

1839-1892: Cambridge U. — Senior Wrangler 1843

1855?: work on multistep methods

1858-1892: Lowndean Professor of Astronomy and Geometry

Declined both knighthood and Astronomer Royal post



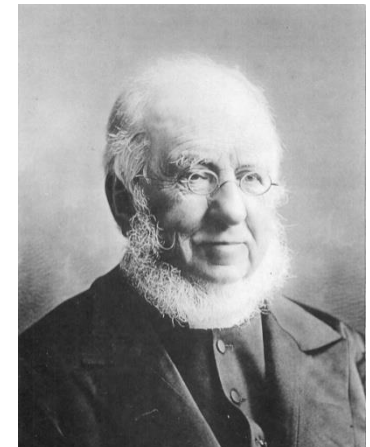
Francis Bashforth 1819-1912

influential ballistics expert

1840-1843: Cambridge U. — Second Wrangler 1843

1864-1872: Prof of Applied Maths, Royal Military Acad, Woolwich

1883: paper on Adams methods (calculating shapes of drops).



Runge-Kutta formulae for ODEs

Like Adams formulas, these are a generalization of Euler. Coriolis 1830s had some 2nd-order formulas. Then —

Carl David Tolme Runge 1856-1927

1895 *Math. Anal.*, “Über die numerische Auflösung...”

Karl Heun 1859-1929

PhD. 1881 Göttingen, Prof. Theoretical Mechanics Karlsruhe

1900 *Zeit. Math. Phys.*, “Neue Methode zur approximativen Integration...”

Martin Wilhelm Kutta 1867-1944

1901 general R-K theory, *Zeit. Math. Phys.*,
“Beitrag zur näherungsweise Integration...”

Also Nyström 1925, Moulton 1926, von Mises 1930,
and in the computer era, John Butcher.



Finite differences for PDEs

Lewis Fry Richardson 1881-1953

Richard Southwell 1888-1970

Richard Courant 1888-1972

Kurt Friedrichs 1901-1982

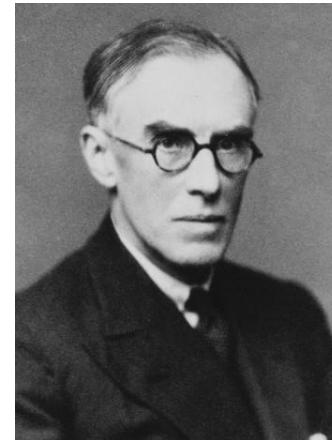
(Natl. Medal of Science 1976)

Hans Lewy 1904-1988

John von Neumann 1903-1957

Peter Lax \approx 1926-

(Natl. Medal of Science 1986)



1940 – 1970

Floating point arithmetic

Konrad Zuse 1910-1995

Civil engineer by training

Worked on computers beginning in 1934

“Zuse Apparatebau” company founded in Berlin 1940

Z1 computer, completed in Berlin **1936**

much further developed: Z3 computer, 1941

22-bit floating point binary arithmetic

(14 bits for fraction, 8 for exponent)

1Hz, programmable, stored data but not program

Machine was destroyed in 1945 air raids

Zuse was also an artist.



Splines

Tiberiu Popoviciu (1906-1975) – Cluj, Romania

Paul de Faget de Casteljaou 1930-2022

French mathematician/physicist

1958-1992: Citroën; unpublished work in **1958**

Pierre Bezier 1910-1999

1933-1975: engineer at Renault

1960: beginning of CAD/CAM work, Bezier curves

Isaac Jacob (“Iso”) Schoenberg 1903-1990

Born in Romania (Landau’s son-in-law). To USA in 1930.

Chicago, Harvard, Princeton, Swarthmore, Colby...

1941-1966: University of Pennsylvania

1943-1945: Army Ballistic Research Laboratory

1946: two papers on splines

1966-1973: U. of Wisconsin

Carl de Boor 1937-

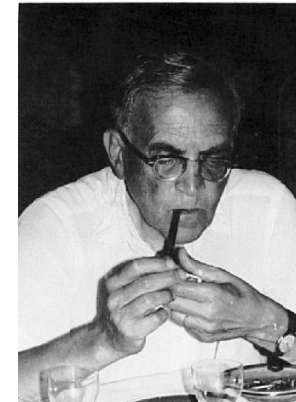
Born in what became East Germany. To USA in 1959.

1960-1964: General Motors (grad student intern)

1962: first of many publications on splines

Purdue, Michigan...

1972-2003: U. of Wisconsin. 2003: National Medal of Science.



S. J. Schoenberg



Monte Carlo simulation methods

Stanislaw Ulam 1909-1984

Born in Poland, to USA in 1935, pure mathematician by training
Princeton, Harvard, Wisconsin, USC

1943-1965: Los Alamos (key figure in hydrogen bomb)

1965-1984: Dept. of Mathematics, U. of Colorado



John von Neumann 1903-1957

Born in Hungary, to USA in 1930, pure mathematician by training
Manhattan Project, Los Alamos, Atomic Energy Comm.

1930-1957: Princeton U. & Inst. Advanced Study



Nicholas Metropolis 1915-1999

Greek-American, physicist by training

Oscillated between **U. of Chicago** and **Los Alamos**

1932, 1941, 1945, 1948, 1957, 1965

1947: Invention by Ulam & von N. for applications in neutron diffusion

1949: publication of "The Monte-Carlo Method" by Ulam & Metropolis

Also Fermi, Richtmyer, ...



Simplex algorithm for linear programming

Leonid Kantorovich 1912-1986

1934-1960 Professor of Mathematics, Leningrad State U.

1939: *Mathematical Methods in the Organization and Planning of Production*

1975: Nobel Prize in Economics



George Dantzig 1914-2005

1941-1946: Head of Combat Analysis Branch,
US Air Force Statistical Control

1944: War Department Exceptional Civilian Service Medal

1946: receives PhD at UC Berkeley

1947: Simplex algorithm

1948: Koopmans coins expression “linear programming”

1947-1952: Mathematical Advisor, US Defense Department

1952-1960: RAND Corporation

1960-1966: UC Berkeley

1966-2005 : Stanford U.

1975: National Medal of Science



Conjugate gradient and Lanczos iterations

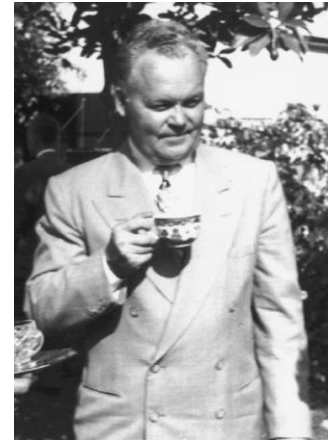
Cornelius Lanczos 1893-1974

Born in Hungary: Fejér, Einstein, ...

1931-1950: Purdue and Boeing

1949-1952: Inst. Numer. Anal., NBS, UCLA

1952-1972: Dublin Inst. Adv. Study, Ireland



Magnus Hestenes 1906-1991

late 1920s-1947: University of Chicago

1947-1973: UCLA

1949-1952: Inst. Numer. Anal., NBS, UCLA

Eduard Stiefel 1909-1978

eminent in geometry and physics as well as computation

Swiss Federal Institute of Technology

1952: landmark papers by Lanczos and Hestenes & Stiefel



Fortran

John Backus 1924-2007

grew up in Delaware, USA

a poor student; disorganized early career
with some years in US Army

1949: AB in Mathematics, Columbia U.

1950-1991 IBM

1954: first paper about Fortran; programming team is built

1957: Fortran released by IBM

1975: National Medal of Science

1977: Turing Award



Stiff ODE solvers

Charles Francis Curtiss 1921-2007

1938-2007: Dept. Chemistry, U. Wisconsin (student, professor, emeritus) interrupted by govt. work in WWII

Joseph Oakland Hirschfelder 1911-1990

1937-1981: Dept. Chemistry, U. Wisconsin

1943-1946: group leader, Los Alamos

1946: Chief Phenomenologist, Bikini Bomb Test

1952: “Integration of stiff equations” with Curtiss, *PNAS*

Nat. Academy of Science; Nat. Medal of Science 1976

Germund Dahlquist 1925-2005

Royal Institute of Technology, Sweden

1963: “A special stability problem for linear multistep methods...”, *BIT*

C. William Gear 1935-2022

1956-1990: U. of Illinois

1965, 1966 and others: visits to Argonne National Lab

1967: first paper on stiff solvers

1971: *Numerical Initial-Value Problems in ODEs*

1990-2000: NEC



Finite elements for PDE

Richard Courant 1888-1972

1943 "Variational methods..."

(landmark paper, but attracted no notice till later)



Finite elements grew out of the aeronautical engineering of the 1950s.
Additional names include Martin, Turner, Irons, Kelsey, Topp.

John H. Argyris 1913-2004

Born in Greece; much of career at U. of Stuttgart, Germany

1960 *Energy Theorems and Structural Analysis*



Ray W. Clough 1920-2016

1950s: Boeing?

1960 "The finite element in plane stress analysis"

1970- : Professor of Structural Engineering, UC Berkeley
eminent authority in earthquake engineering

1994: National Medal of Science



Other key early figures include Babuška, Zienkewicz, Strang

Orthogonal linear algebra

Wallace Givens 1911-1993

1950s and 1960s: Argonne National Laboratory
Later, professor at U. of Tennessee

1958: introduction of Givens rotations



Alston Householder 1904-1993

1946-1969: Oak Ridge National Laboratory

1958: 4-page paper introducing Householder reflections

1964: *The Theory of Matrices in Numerical Analysis*



Gene Golub 1932-2007

Professor at Stanford from mid-1960s.

Key early contributions to many topics including SVD
and least-squares

1965: “Numerical methods for solving
linear least-squares problems”



QR algorithm for matrix eigenvalues

Heinz Rutishauser 1918-1970

ETH Zurich

1958 LR algorithm

V. N. Kublanovskaya 1920-2012

Steklov Institute of Mathematics, St. Petersburg

1961 "On some algorithms..."

J. G. F. Francis 1934-

Late 1950s: National Research Development Corporation, London
Assistant of Christopher Strachey

1961 "The QR transformation..." I & II, *Computer J.*

James H. Wilkinson 1919-1986

Undergraduate in Mathematics at Cambridge

1940-1946: war work related to numerics and ballistics

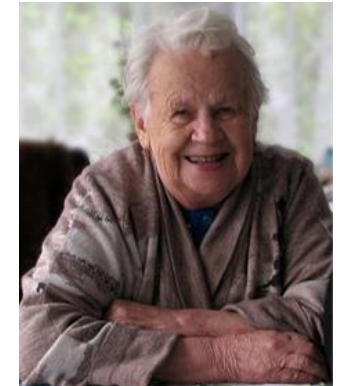
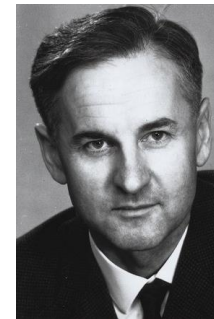
1946: Turing's assistant on Pilot Ace Computer

1946-1986: National Physical Laboratory

1965: *The Algebraic Eigenvalue Problem*

1969: FRS

1970: Turing Award



Fast Fourier Transform

Gauss 1805 (unpublished) age 28, 2 years before Fourier!

Runge 1903 Yates 1937 Stumpff 1939

Thomas 1948 Danielson & Lanczos 1942 Good 1958

Wheeler... Gentleman...

Modern birth due to Tukey & Garwin & Sande in 1963, leading to
1965 Cooley-Tukey paper in *Mathematics of Computation*

John Tukey 1915-2000

Princeton University, founder of Statistics Dept.

(also Bell Labs and consultant to U.S., govt. & industry)

1973: National Medal of Science.

Coiner of terms "FFT", "software", "bit", "stiff" (?)

Richard Garwin 1928-

Watson Scientific Lab, Columbia U. (later at TJ Watson)

Well known physicist with major involvement in H-bomb

FFT motivation related to detection of Soviet nuclear tests.

James W. Cooley 1926-2016

IBM TJ Watson Research Center. U. Rhode Island.



Quasi-Newton iterations for optimization

The field was launched between 1959 and 1970.

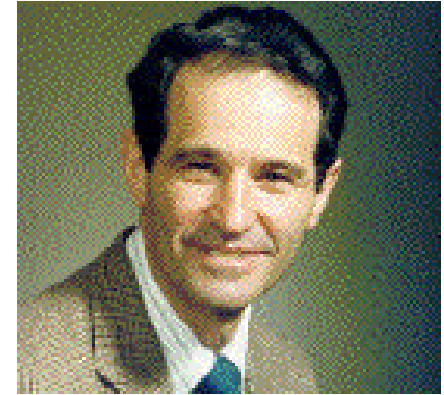
William Davidon 1927-2013

1954 PhD in Physics, U. Chicago

1959: “variable metric” report at Argonne National Lab.

(It was finally published in 1991, first issue of *SIOPT*)

1961-1991: Prof. of Physics and Maths, Haverford Coll



Michael Powell 1936-2015

1959-1976 Harwell A.E.R.E.

1976- DAMTP, U. of Cambridge

1983 FRS

Charles Broyden 1933-2011

1955-1965: English Electric

1965: “good” and “bad” Broyden methods

1967-1986 U. of Essex

1990-2003 U. of Bologna

Roger Fletcher 1939-2016

1969-1973 Harwell A.E.R.E.... U. of Leeds

1963: Davidon-Fletcher-Powell paper

1971-2005 U. of Dundee

2003 FRS



1970 – 2000

Preconditioning for iterative solution of linear systems

Many people contributed to the discovery of preconditioning, including Evans, Varga, Wachspres, Golub, Concus and O'Leary. Yet there was a particular preconditioner that made the idea famous and is still one of the most effective today: incomplete factorization.

Henk van der Vorst 1944-

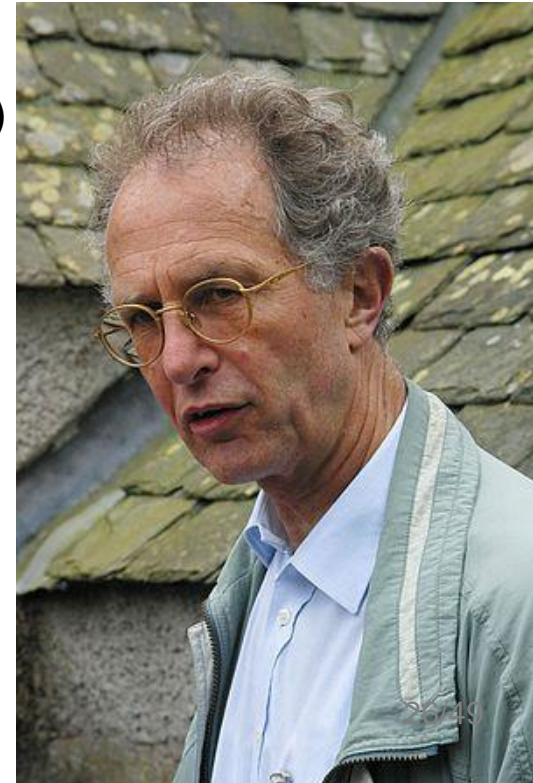
1970s-2005: Universities of Delft and Utrecht, Netherlands

1977: original paper on incomplete LU factorization

2006: knighted (Ridder in de Orde van de Nederlandse Leeuw)



one of van der Vorst's
watercolors



Spectral methods for PDE

Important work in 1950s and 1960s by Lanczos, Clenshaw, Elliott, Fox and Mason et al.
Contributions also from Kreiss and Oliger and others.
These methods were made famous by:

Steve Orszag 1943-2011

1966?-1984: Applied Mathematics, MIT

1971: series of major papers on spectral methods in fluid mechanics
(Orszag coined the phrase “spectral methods”)

1984-1998: Prof. of Applied Mathematics, Princeton U.

1998-? Prof. of Mathematics, Yale U.

David Gottlieb 1944-2008

From Israel; came to USA in 1972

1972-1976: MIT and ICASE (NASA Langley)

1977: spectral methods book by D.G. and S.A.O.

1976-1985: Dept. of Applied Mathematics, Tel-Aviv U.

1985-2008: Prof. of Applied Mathematics, Brown U.



MATLAB

Cleve Moler 1939-

Author of EISPACK, LINPACK, four textbooks

high school Utah, BA Caltech, PhD Stanford

1965-1973: U. of Michigan

1973-1984: U. of New Mexico

strong links with Argonne National Laboratory

1977: creation of first version of Matlab

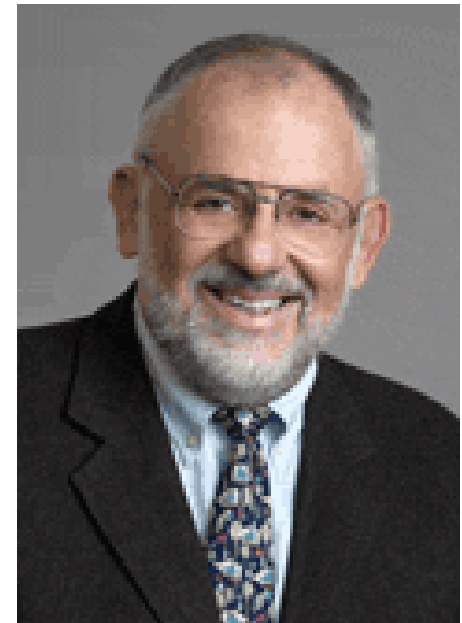
1984: Jack Little founds MathWorks

1985: first Matlab sale (Feb. 10)

1984-1989: Moler employed at Intel and Ardent

1989: joins MathWorks as Chief Scientist

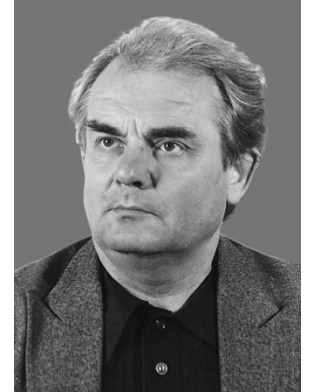
Matlab is 2/3 as old as Fortran!



Multigrid Methods for PDE

R. P. Fedorenko 1930-2009

1961: invention of 2-grid and later multigrid method.
This work extended also by N. S. Bakhvalov, 1966.



Achi Brandt 1938-

1963- : Applied Mathematics, Weizmann Institute, Israel
1973: first paper on multigrid methods
1977: 57-page paper in *Mathematics of Computation*



Wolfgang Hackbusch 1948-

1976: Independent rediscovery of multigrid
1982-?: Professor of Applied Maths., U. Kiel
199?-?: director of Max-Planck Inst. In Leipzig



IEEE arithmetic

William (“Velvel”) Kahan 1933-

late 1960s- : Dept. of Mathematics, UC Berkeley

1977: the draft IEEE floating-point standard released

1985: adoption of the standard after much wrangling

1989: Turing Award



Nonsymmetric Krylov iterations for large matrix problems

Many contributors including Arnoldi, Elman, Schultz, Freund, Gutknecht.

P. K. W. Vinsome 19??-

Physicist at Shell Petroleum Co.

1976 paper on Orthomin

Yousef **Saad** 1950-

Yale University, U. of Minnesota

1986: GMRES paper with Schultz

Henk van der Vorst 1944-

Professor of Mathematics at U. of Utrecht

1986: BiCGSTAB paper—most cited maths paper in 1990s

1996: Jacobi-Davidson paper with Sleijpen

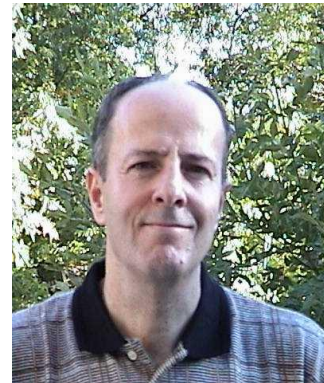
Dan Sorensen 1947-

Argonne National Laboratory

Rice U.

1992: implicitly restarted Arnoldi

1996: *ARPACK User's Guide* with Lehoucq and Yang



Interior Point Methods for optimization

Earlier work by Carroll (1961) and Khachiyan (1979) and also by Fiacco & McCormick (1968), Margaret Wright (1976) and others on barrier methods.

Narendra Karmarkar 1957-

1978: BTech in Elect. Engr., IIT Bombay

1982?: PhD, U. C. Berkeley

1983-? AT&T Bell Labs

1984 :“A new polynomial time algorithm for linear programming,” *Combinatorica*

Now lives in India



Fast Multipole Method for N -body simulation and more

Related earlier work by Barnes & Hut & others

Vladimir Rokhlin 1952–

Born in USSR; to USA in late 1970s

1976-1985: Exxon Production Research Co.

1983: PhD in Applied Mathematics, Rice U.

1985 “Rapid solution of integral equations...”

1985- Prof. of Computer Science, Yale U.



Leslie Greengard 1958–

From Boston, New York, New Haven

1987 M.D. and Ph.D. (Comp. Sci.) Yale U.

1987 “A fast algorithm for particle simulations”, with Rokhlin

1989- Prof. of Mathematics, Courant Inst., NYU

2013- Director, Simons Center for Data Analysis



Both VR and LG had eminent fathers.

Wavelets

Jean Morlet 1931-2007

Geophysicist at Elf Aquitaine / Oric

Work beginning 1975 leads to major publication **1982**

Also Alex Grossmann 1984, Stephane Mallat 1989,
Yves Meyer 1986 (2017 Abel Prize)

Ingrid Daubechies 1954-

Training in physics and mathematics

From Belgium; came to USA in 1987

1975-1987: Vrije Universiteit Brussel

1987-1994: AT&T Bell Labs; Rutgers U.

Big change in 1980s physics → mathematics

1988: “Orthonormal bases of compactly supported wavelets”

1993-2010: Princeton U.; 2011- : Duke U.

MacArthur Prize, honorary degree from Oxford, much more...



Automatic differentiation

Many antecedents including Beda (1959), Wengert (1964), Linnainmaa (1970), Speelpenning (1980), Kedem (1980), Rall (1981), Baur and Strassen (1984), LeCun 1985, Bischof & Carle (ADIFOR, 1991).

A central figure in the modern rebirth of these ideas (in particular the use of “reverse mode”) was

Andreas Griewank 1950-2021

Argonne National Laboratory
Institute for Scientific Computing, TU Dresden
Humboldt-University Berlin
2015-2018: Dean, Yachay Tech, Ecuador

These days the most famous applications are in **back-propagation**.



The Inventors

Adams	Argyris	Backus	Bashforth
Bezier	Brandt	Broyden	Clough
Cooley	Courant	Curtiss	Dahlquist
Dantzig	Daubechies	Davidon	de Boor
de Casteljau	Euler	Fedorenko	Fletcher
Francis	Friedrichs	Garwin	Gauss
Gear	Givens	Golub	Gottlieb
Greengard	Griewank	Hackbusch	Hestenes
Heun	Hirschfelder	Householder	Liu
Jacobi	Kahan	Kantorovich	Karmarkar
Kublanovskaya	Kutta	Lagrange	Lanczos
Lax	Legendre	Lewy	Metropolis
Moler	Morlet	von Neumann	Newton
Orszag	Powell	Raphson	Richardson
Rokhlin	Runge	Rutishauser	Saad
Schoenberg	Sorensen	Southwell	Stiefel
Tukey	Ulam	van der Vorst	Vinsome
Wilkinson	Zuse		

Who was an engineer?

Adams

Bezier

Cooley

Dantzig

de Casteljau

Francis

Gear

Greengard

Heun

Jacobi

Kublanovskaya

Lax

Moler

Orszag

Rokhlin

Schoenberg

Tukey

Wilkinson

Argyris

Brandt

Courant

Daubechies

Euler

Friedrichs

Givens

Griewank

Hirschfelder

Kahan

Kutta

Legendre

Morlet

Powell

Runge

Sorensen

Ulam

Zuse

Backus

Broyden

Curtiss

Davidon

Fedorenko

Garwin

Golub

Hackbusch

Householder

Kantorovich

Lagrange

Lewy

von Neumann

Raphson

Rutishauser

Southwell

van der Vorst

Bashforth

Clough

Dahlquist

de Boor

Fletcher

Gauss

Gottlieb

Hestenes

Liu

Karmarkar

Lanczos

Metropolis

Newton

Richardson

Saad

Stiefel

Vinsome

Who was a physicist?

Adams

Bezier

Cooley

Dantzig

de Casteljou

Francis

Gear

Greengard

Heun

Jacobi

Kublanovskaya

Lax

Moler

Orszag

Rokhlin

Schoenberg

Tukey

Wilkinson

Argyris

Brandt

Courant

Daubechies (1/2)

Euler

Friedrichs

Givens

Griewank

Hirschfelder

Kahan

Kutta

Legendre

Morlet

Powell

Runge

Sorensen

Ulam

Zuse

Backus

Broyden

Curtiss

Davidon

Fedorenko

Garwin

Golub

Hackbusch

Householder

Kantorovich

Lagrange

Lewy

von Neumann

Raphson

Rutishauser

Southwell

van der Vorst

Bashforth

Clough

Dahlquist

de Boor

Fletcher

Gauss (1/2)

Gottlieb

Hestenes

Liu

Karmarkar

Lanczos

Metropolis

Newton (1/2)

Richardson

Saad

Stiefel

Vinsome

Who was a chemist?

Adams	Argyris	Backus	Bashforth
Bezier	Brandt	Broyden	Clough
Cooley	Courant	Curtiss	Dahlquist
Dantzig	Daubechies	Davidon	de Boor
de Casteljau	Euler	Fedorenko	Fletcher
Francis	Friedrichs	Garwin	Gauss
Gear	Givens	Golub	Gottlieb
Greengard	Griewank	Hackbusch	Hestenes
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Rokhlin	Runge	Rutishauser	Saad
Schoenberg	Sorensen	Southwell	Stiefel
Tukey	Ulam	van der Vorst	Vinsome
Wilkinson	Zuse		

Who was a mathematician?

Adams	Argyris	Backus	Bashforth
Bezier	Brandt	Broyden	Clough
Cooley	Courant	Curtiss	Dahlquist
Dantzig	Daubechies (1/2)	Davidon	de Boor
de Casteljau	Euler	Fedorenko	Fletcher
Francis	Friedrichs	Garwin	Gauss (1/2)
Gear	Givens	Golub	Gottlieb
Greengard	Griewank	Hackbusch	Hestenes
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Kublanovskaya	Kutta	Lagrange	Lanczos
Lax	Legendre	Lewy	Metropolis
Moler	Morlet	von Neumann	Newton (1/2)
Orszag	Powell	Raphson	Richardson
Rokhlin	Runge	Rutishauser	Saad
Schoenberg	Sorensen	Southwell	Stiefel
Tukey	Ulam	van der Vorst	Vinsome
Wilkinson	Zuse		

(Including computer scientists and statisticians, since very hard to distinguish)

Who was a professor?

Adams

Bezier

Cooley

Dantzig

de Casteljau

Francis

Gear

Greengard

Heun

Jacobi

Kublanovskaya

Lax

Moler

Orszag

Rokhlin

Schoenberg

Tukey

Wilkinson

Argyris

Brandt

Courant

Daubechies

Euler

Friedrichs

Givens

Griewank

Hirschfelder

Kahan

Kutta

Legendre

Morlet

Powell

Runge

Sorensen

Ulam

Zuse

Backus

Broyden

Curtiss

Davidon

Fedorenko

Garwin

Golub

Hackbusch

Householder

Kantorovich

Lagrange

Lewy

von Neumann

Raphson

Rutishauser

Southwell

van der Vorst

Bashforth

Clough

Dahlquist

de Boor

Fletcher

Gauss

Gottlieb

Hestenes

Liu

Karmarkar

Lanczos

Metropolis

Newton

Richardson

Saad

Stiefel

Vinsome

(Including English academics like Raphson with titles other than professor)

Who had major involvement with government or industry?

Adams	Argyris	Backus	Bashforth
Bezier	Brandt	Broyden	Clough
Cooley	Courant	Curtiss	Dahlquist
Dantzig	Daubechies	Davidon	de Boor
de Casteljou	Euler	Fedorenko	Fletcher
Francis	Friedrichs	Garwin	Gauss
Gear	Givens	Golub	Gottlieb
Greengard	Griewank	Hackbusch	Hestenes
Heun	Hirschfelder	Householder	Liu
Jacobi	Kahan	Kantorovich	Karmarkar
Kublanovskaya	Kutta	Lagrange	Lanczos
Lax	Legendre	Lewy	Metropolis
Moler	Morlet	von Neumann	Newton
Orszag	Powell	Raphson	Richardson
Rokhlin	Runge	Rutishauser	Saad
Schoenberg	Sorensen	Southwell	Stiefel
Tukey	Ulam	van der Vorst	Vinsome
Wilkinson	Zuse		

59%

(i.e., at the time of their big contributions)

Who was British?

Adams

Bezier

Cooley

Dantzig

de Casteljau

Francis

Gear

Greengard

Heun

Jacobi

Kublanovskaya

Lax

Moler

Orszag

Rokhlin

Schoenberg

Tukey

Wilkinson

Argyris

Brandt

Courant

Daubechies

Euler

Friedrichs

Givens

Griewank

Hirschfelder

Kahan

Kutta

Legendre

Morlet

Powell

Runge

Sorensen

Ulam

Zuse

Backus

Broyden

Curtiss

Davidon

Fedorenko

Garwin

Golub

Hackbusch

Householder

Kantorovich

Lagrange

Lewy

von Neumann

Raphson

Rutishauser

Southwell

van der Vorst

Bashforth

Clough

Dahlquist

de Boor

Fletcher

Gauss

Gottlieb

Hestenes

Liu

Karmarkar

Lanczos

Metropolis

Newton

Richardson

Saad

Stiefel

Vinsome

Who was German/Swiss/Austrian?

Adams	Argyris	Backus	Bashforth
Bezier	Brandt	Broyden	Clough
Cooley	Courant	Curtiss	Dahlquist
Dantzig	Daubechies	Davidon	de Boor
de Casteljau	Euler	Fedorenko	Fletcher
Francis	Friedrichs	Garwin	Gauss
Gear	Givens	Golub	Gottlieb
Greengard	Griewank	Hackbusch	Hestenes
Heun	Hirschfelder	Householder	Liu
Jacobi	Kahan	Kantorovich	Karmarkar
Kublanovskaya	Kutta	Lagrange	Lanczos
Lax	Legendre	Lewy	Metropolis
Moler	Morlet	von Neumann	Newton
Orszag	Powell	Raphson	Richardson
Rokhlin	Runge	Rutishauser	Saad
Schoenberg	Sorensen	Southwell	Stiefel
Tukey	Ulam	van der Vorst	Vinsome
Wilkinson	Zuse		

Who was born in the USA?

Adams

Bezier

Cooley

Dantzig

Bezier

Francis

Gear

Greengard

Heun

Jacobi

Kublanovskaya

Lax

Moler

Orszag

Rokhlin

Schoenberg

Tukey

Wilkinson

Argyris

Brandt

Courant

Daubechies

Euler

Friedrichs

Givens

Griewank

Hirschfelder

Kahan

Kutta

Legendre

Morlet

Powell

Runge

Sorensen

Ulam

Zuse

Backus

Broyden

Curtiss

Davidon

Fedorenko

Garwin

Golub

Hackbusch

Householder

Kantorovich

Lagrange

Lewy

von Neumann

Raphson

Rutishauser

Southwell

van der Vorst

Bashforth

Clough

Dahlquist

de Boor

Fletcher

Gauss

Gottlieb

Hestenes

Liu

Karmarkar

Lanczos

Metropolis

Newton

Richardson

Saad

Stiefel

Vinsome

Who ended up in the USA?

Adams

Bezier

Cooley

Dantzig

de Casteljau

Francis

Gear

Greengard

Heun

Jacobi

Kublanovskaya

Lax

Moler

Orszag

Rokhlin

Schoenberg

Tukey

Wilkinson

Argyris

Brandt

Courant

Daubechies

Euler

Friedrichs

Givens

Griewank

Hirschfelder

Kahan

Kutta

Legendre

Morlet

Powell

Runge

Sorensen

Ulam

Zuse

Backus

Broyden

Curtiss

Davidon

Fedorenko

Garwin

Golub

Hackbusch

Householder

Kantorovich

Lagrange

Lewy

von Neumann

Raphson

Rutishauser

Southwell

van der Vorst

Bashforth

Clough

Dahlquist

de Boor

Fletcher

Gauss

Gottlieb

Hestenes

Liu

Karmarkar

Lanczos

Metropolis

Newton

Richardson

Saad

Stiefel

Vinsome

Who won the USA National Medal of Science?

Adams	Argyris	Backus <i>Turing</i>	Bashforth
Bezier	Brandt	Broyden	Clough
Cooley	Courant	Curtiss	Dahlquist
Dantzig	Daubechies <i>Mac Arthur</i>	Davidon	de Boor
de Casteljau	Euler <i>GMAT</i>	Fedorenko	Fletcher
Francis	Friedrichs	Garwin	Gauss <i>GMAT</i>
Gear	Givens	Golub	Gottlieb
Greengard	Griewank	Hackbusch	Hestenes
Heun	Hirschfelder	Householder	Liu
Jacobi <i>GMAT</i>	Kahan <i>Turing</i>	Kantorovich <i>Nobel</i>	Karmarkar
Kublanovskaya	Kutta	Lagrange	Lanczos
Lax <i>Abel</i>	Legendre	Lewy	Metropolis
Moler	Morlet	von Neumann <i>GMAT</i>	Newton <i>GMAT</i>
Orszag	Powell	Raphson	Richardson
Rokhlin	Runge	Rutishauser	Saad
Schoenberg	Sorensen	Southwell	Stiefel
Tukey	Ulam	van der Vorst	Vinsome
Wilkinson <i>Turing</i>	Zuse		

How old were they?

eligible for the Fox Prize!

Adams 36

Bezier 50

Cooley 39

Dantzig 33

de Casteljau 28

Francis 27

Gear 32

Greengard 29

Heun 41

Jacobi 22,40

Kublanovskaya 32

Lax 35

Moler 38

Orszag 28

Rokhlin 33

Schoenberg 43

Tukey 50

Wilkinson 46

Argyris 47

Brandt 35

Courant 40,57

Daubechies 34

Euler 59

Friedrichs 27

Givens 47

Griewank 40

Hirschfelder 41

Kahan 44

Kutta 34

Legendre 53

Morlet ?

Powell 27

Runge 45

Sorensen 45

Ulam 38

Zuse 26

Backus 30

Broyden 32

Curtiss 31

Davidon 32

Fedorenko ?

Garwin 37

Golub 33

Hackbusch 28

Householder 54

Kantorovich 27

Lagrange 23

Lewy 24

von Neumann 44

Raphson 42

Rutishauser 28

Southwell 52

van der Vorst 33,42

Vinsome ?

Bashforth 64

Clough 39

Dahlquist 38

de Boor 25

Fletcher 24

Gauss 18,32,37

Gottlieb 33

Hestenes 46

Liu 43

Karmarkar 27

Lanczos 59

Metropolis 33

Newton 27

Richardson 35

Saad 36

Stiefel 43

Vinsome ?

So, ivory tower or coal face?

The answer seems to be a blend:

Most of the big algorithms were invented by
academic mathematicians
who had
MAJOR involvement
with applications in industry or government.

What are the great numerical algorithms of the 21st century?

