NUMERICAL LINEAR ALGEBRA WITH APPLICATIONS

Volume 17 Number 5 October 2010

Editor-in-Chief
Panayot Vassilevski

Special Issue:
Dedicated to the memory of David M. Young, Jr.
Guest Editors: Owe Axelsson and David R. Kincaid

NLAAEM 17(5) 741–870 (2010)
ISSN 1070-5325
View this journal online at wileyonlinelibrary.com

NUMERICAL LINEAR ALGEBRA WITH APPLICATIONS

AIMS AND SCOPE

This journal is directed at researchers in Numerical Analysis, Computer Sciences and Natural Sciences, engineers and economists who either take part in the development of methods in Numerical Linear Algebra or use such methods in their research.

Topics covered include (but are not limited to):
Conjugate Gradients Like and other iterative methods; Preconditioning Methods; Direct Solution Methods; Numerical Methods for Eigenproblems; Newton-like Methods for Nonlinear Equations; Parallel and Vectorizable Algorithms in Numerical Linear Algebra; Application of Methods of Numerical Linear Algebra in Science, Engineering and Economics

The journal emphasizes mathematical rigour in presenting new methods in Numerical Linear Algebra including their analysis and applications. Where it turns out to be difficult to give full mathematical rigour to the presentation, well-chosen numerical test

problems can suffice to demonstrate the usefulness of the presented method, if these are accompanied by a discussion and heuristic explanations.

The journal also emphasizes analysis of the computational and communication complexity of algorithms in Numerical Linear Algebra when implemented in different computer architectures.

The journal solicits original research papers and survey articles. All papers should contain a discussion indicating in which application(s) the approach, suggested in the paper, can be used and mention such applications shortly also in the abstract of the paper. The authors should strive at ensuring that the presented methods are easily understandable by as broad a spectrum of readers as possible.

NUMERICAL LINEAR ALGEBRA WITH APPLICATIONS
(*Numer. Linear Algebra Appl.*)

CONTENTS

VOLUME 17, ISSUE No. 5 October 2010

Special Issue:

Dedicated to the memory of David M. Young, Jr.

Guest Editors: Owe Axelsson and David R. Kincaid

PREFACE: O. Axelsson and D. R. Kincaid 741

The life and times of Dr David M. Young, Jr: D. R. Kincaid, R. S. Varga and C. H. Warlick 743

A new multilevel algebraic preconditioner for the diffusion equation in heterogeneous media: Y. Kuznetsov and A. Prokopenko 759

Efficient algorithms for multiscale modeling in porous media: M. F. Wheeler, T. Wildey and G. Xue 771

Preconditioning of matrices partitioned in 2 × 2 block form: Eigenvalue estimates and Schwarz DD for mixed FEM: O. Axelsson and R. Blaheta 787

Incremental incomplete LU factorizations with applications: C. Calgaro, J.-P. Chehab and Y. Saad 811

Second-order treatment of the interface of domain decomposition method for parabolic problems: Y. Jun and T.-Z. Mai 839

Condition number bounds and mesh quality: L. Branets and G. F. Carey 855

Numerical Linear Algebra with Applications is covered by the following abstracting and indexing services: 'CompuMath Citation Index® (Thomson ISI), Computer Abstracts International Database (Emerald), Computer Science Index (EBSCO), Current Contents®/Physical, Chemical & Earth Sciences (Thomson ISI), Current Index to Statistics (ASA/IMS), Journal Citation Reports/Science Edition (Thomson ISI), Mathematical Reviews/MathSciNet/Current Mathematical Publications (AMS), Science Citation Index Expanded™ (Thomson ISI) Science Citation Index® (Thomson ISI), SCOPUS (Elsevier), Statistical Theory & Method Abstracts (International Statistical Institute), Web of Science® (Thomson ISI), Zentralblatt MATH/Mathematics Abstracts (FIZ Karlsruhe)'.

NLAAEM 17(5) 741–870 (2010)
ISSN 1070–5325

NUMERICAL LINEAR ALGEBRA WITH APPLICATIONS
Numer. Linear Algebra Appl. 2010; **17**:741–742
Published online in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/nla.752

Preface

Owe Axelsson[1] and David R. Kincaid[2,*,†]

[1]*Uppsala University and Institute of Geonics, ASCR, Ostrava, Czech Republic*
[2]*The University of Texas at Austin, TX, U.S.A.*

This special issue is dedicated to the memory of David M. Young, Jr. (October 20, 1923–December 21, 2008), who was an American mathematician and computer scientist affiliated with The University of Texas at Austin for most of his life.

Dr. Young was one of the pioneers of modern numerical analysis. He was best known for establishing the mathematical foundation for the successive overrelaxation (SOR) method in his Harvard University doctoral research under the supervision of Professor Garret Birkhoff. In his 1950 dissertation, *Iterative methods for solving partial differential equations of elliptic type*, he showed that it was possible to automate the relaxation process for use on computing machines. Previously, it was believed that this could only be done using hand-computations on calculators by groups such as those under the direction of R. V. Southwell, for example. Furthermore, he derived an expression for the optimal relaxation factor under a condition, he named *Property A*.

David Young held several jobs in industry, for instance, as a mathematician at the Computing Laboratory of the Aberdeen Proving Ground, Maryland, and as a manager of the Mathematical Analysis Department at the Ramo-Wooldridge Corporation, Los Angeles, California. He began his academic career at the University of Maryland, College Park. In 1958, he joined the faculty of the University of Texas in Austin as a Professor of Mathematics and as the first Director of the Computation Center. In 1970, he became the founding Director of the Center for Numerical Analysis, which is now a part of the University's Institute for Computational Engineering and Sciences. In 1982, David Young was awarded a distinguished professorship, an *Ashbel Smith Professor of Mathematics and Computer Sciences*, at The University of Texas at Austin.

David Young is best known for his research on iterative solution methods for solving large sparse systems of linear equations. Such systems arise primarily in the numerical solution of partial differential equations, which had been discretized by either finite differences or finite elements. One of his early accomplishments was the analysis of the SOR method for consistently ordered matrices. Also, he was among the first to use the symmetric successive overrelaxation (SSOR) method, norms of matrices for iterative methods, Chebyshev polynomials for accelerating the iterative solution methods, adaptive procedures for determining iteration parameters, conjugate gradient methods with emphasis on generalizations for nonsymmetric systems, higher order discretization schemes for partial differential equations, and procedures for estimating the accuracy of the approximate

*Correspondence to: David R. Kincaid, The University of Texas at Austin, TX, U.S.A.
†E-mail: kincaid@mail.utexas.edu

solution of a linear system. Moreover, he studied vectorization and parallelization aspects of preconditioned iterative solution methods.

David Young published numerous scientific papers and several books in numerical analysis. The two most relevant books for numerical linear algebra were *Iterative Solution of Large Linear Systems*, Academic Press, 1971, and *Applied Iterative Methods*, Academic Press, 1981, co-authored with Louis A. Hageman. Also, Professor Young wrote a two-volume book with the late Robert Todd Gregory, entitled *A Survey of Numerical Mathematics*, Addison-Wesley, 1972, 1973. (All of these books were republished by Dover.)

David had not only a major impact on the development of scientific computing, but also on the lives of his students, colleagues, and friends. He was an international scientific leader during the first 50 years of the modern computer era. Professor Young was an inspiring teacher and a fine gentleman. At conferences, David was friendly and generous with his time advising and counseling graduate students on both mathematical problems and personal issues. Dr. Young's spirit remains alive in the memories of all of those, like the undersigned, who had the privilege of knowing or working with him.

The contents of this special issue reflect on David Young's life and research. All the authors of the papers have known and respected him for years.

The initial contribution by David Kincaid, Richard Varga and Charles Warlick presents an outline of David Young's rich life, accomplishments, and work. It includes his family background in addition to his career and research.

Next, Mary Wheeler and co-authors present a new method that deals with a topic that has been long been at the forefront of her research in Texas—the Darcy flow problems in porous media. A multi-scale preconditioning strategy is used that minimizes the computational costs associated with the construction of the multi-scale mortar basis functions.

The contribution by Yuri Kuznetsov and coauthor deals with a new multi-level algebraic preconditioner for diffusion–reaction problems in highly heterogeneous media. The preconditioner is based on a special coarsening algorithm using an inner iterative procedure. This results utilizes the independence of the condition number of the preconditioned matrix on the diffusion coefficient.

Owe Axelsson and Radim Blaheta present a general approach to construct preconditioners for finite element matrices applicable to symmetric and unsymmetric problems as well as for positive definite and indefinite problems. Special attention is devoted to problems of saddle point type.

The paper by Yousef Saad and coauthors deals with an incremental LU factorization in applications with a slowly varying sequence of matrices that arise in the solution of time-dependent partial differential equations. To avoid wasteful recomputations of the entire LU factorization, various preconditioning techniques (such as based on approximate inverses) are used to enable cheaper updates of the incomplete factorizations.

Tsun-Zee Mai and co-author present a treatment of interface lines in a strip-wise domain decomposition method leading to second-order accuracy. Also, the optimal overrelaxation parameter is estimated when this problem is solved using the SOR method.

The contribution of Graham Carey and co-author discusses the influence of mesh quality on the condition numbers of the mass matrix, the stiffness matrix, and their computable bounds. In some cases, the mesh distortion causes the bounds on the condition number to be too big. The results are illustrated with several examples taken from practical applications.

All contributions in this special issue deal with research topics of current interest that reflect, in various ways, the influence of David Young's work.

DOI: 10.1002/nla

NUMERICAL LINEAR ALGEBRA WITH APPLICATIONS
Numer. Linear Algebra Appl. 2010; **17**:743–757
Published online 27 January 2010 in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/nla.690

The life and times of Dr David M. Young, Jr

David R. Kincaid[1,*,†], Richard S. Varga[2] and Charles H. Warlick[1]

[1]*Department of Computer Sciences, University of Texas at Austin, Austin, TX 78712, U.S.A.*
[2]*Institute for Computational Mathematics, Kent State University, Kent, OH 44242, U.S.A.*

SUMMARY

Professor David M. Young, Jr was instrumental in the development of iterative algorithms and software for solving large sparse systems of linear algebraic equations of the type that typically arise in the numerical solution of partial differential equations. We present a brief overview of his life, accomplishments, and research. Copyright © 2010 John Wiley & Sons, Ltd.

Received 31 August 2009; Revised 13 October 2009; Accepted 13 November 2009

KEY WORDS: David M. Young, Jr; David Young's equation; iterative methods; ITPACK software; numerical analysis: scientific computing; successive overrelaxation (SOR); supercomputers, Young Instructorship

1. INTRODUCTION

Dr David M. Young, Jr (20 October 1923–21 December 2008) was an international pioneer in numerical analysis, whose career parallels the first 50 years of the modern scientific computing era. David's research activities involved the numerical solution of partial differential equations using iterative methods, especially those adaptable for use on high-performance computers. His early research on iterative methods established the mathematical framework of the successive overrelaxation (SOR) method for consistently ordered matrices. Combining his intellectual ability with hard work, David was able to rise from a first generation immigrant family to obtain a Harvard post graduate education. He became a world-wide leader and an authority in the new scientific area of *numerical analysis*, also known as *scientific computing*, with his specialty being *iterative methods* and *preconditioning*.

*Correspondence to: David R. Kincaid, Institute for Computational Engineering and Sciences, 1 University Station C0200, University of Texas at Austin, Austin, TX 78712, U.S.A.
†E-mail: kincaid@cs.utexas.edu

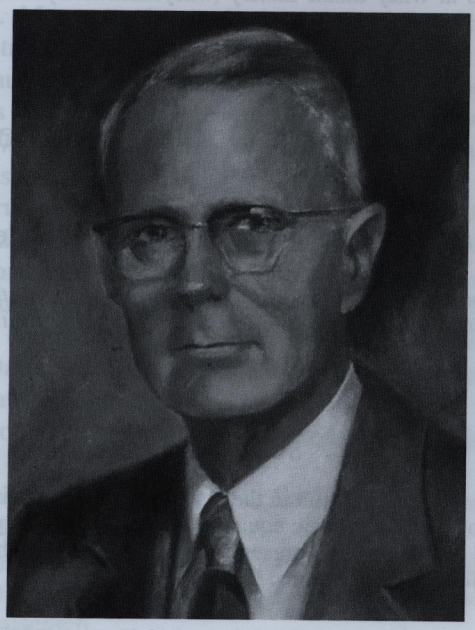

Figure 1. Dr David M. Young, Jr (painted by his sister Christine in 1988).

2. EARLY YEARS

David's parents (David Monaghan Young, from Alva, Scotland, and Madge Colby Tooker Young, from Waterville, Maine) were married in 1923, and they had two children: David Monaghan Young, Jr, and Christine Elva Young, (now) Sorenson.

David Monaghan Young, Jr, and Mildred Victoria Acker (who would become David's wife) were classmates from the eighth grade in North Quincy Junior High throughout their school days at North Quincy High School. David graduated second and Mildred fifth, in their 1941 high school class of over 300 students. (In their high school year book are quotes that still seem appropriate: '*To do easily, what is difficult for others, is a mark of talent*' is next to David's photo, and '*She has won golden opinions, from all sides*,' is next to Mildred's photo).

From an early age David was interested in mathematics. In high school, he was given a special class in Calculus—the other students had not reached that level in mathematics. In fact, David excelled in whatever interested him. David's father taught him to play tennis, and David became an avid tennis player throughout his life.

David's parents knew that he was intelligent, but they did not have enough money for his college education! These were difficult times—the country was coming out of the Great Depression, and David's father had lost his job as an accountant. Fortunately, David's mother had found work at the S.S. Pierce Grocery, and, in later years, she worked as a Ward Secretary at the Quincy City Hospital. To help out, David worked at odd jobs such as delivering magazines door-to-door (using his bicycle to carry them), and tutoring the neighborhood students in mathematics. David wanted a college education, but it seemed out of reach!

DOI: 10.1002/nla

3. WEBB INSTITUTE OF NAVAL ARCHITECTURE

David's friend, Harrison Jones, who was a student at the Webb Institute of Naval Architecture, encouraged David to take the Webb entrance exam. Since the entrance exam was quite hard and competitive, Harrison offered to help David prepare for it. Webb admitted only 20 students each year, and gave them full scholarships that included tuition, room and board, as well as textbooks. By doing well on the entrance exam, David was assured of an all-expenses-paid college education! (At that time, Webb was a private college in the Bronx, New York. Now it is in Glen Cove, Long Island, New York, with the name changed to Webb Institute).

David had been offered an undergraduate scholarship to Harvard University, and another one to MIT. He did not accept either of them because they did not cover *all* of his college expenses—he had no other money. David's Aunt, Elva Tooker, wanted David to go to Harvard, and she even offered to give him some money. She was disappointed that David did not go there, but she was pleased when, some years later, he did go to Harvard!

In September 1941, David started college at Webb. After the attack on Pearl Harbor on 7 December 1941, many young men in the U.S. were joining the military to help in the war effort. (This included almost all of David's entire class of undergraduate students.) Since officers would be needed later in the war, David's elite class of students was told that they should stay at Webb, and finish their degrees, but on an accelerated basis.

The President of Webb was an Admiral in the Navy, who shared David's love of tennis. Frequently, David was asked to play tennis with Admiral Rock on Sunday mornings—even though David was only an undergraduate student. Today, there is a photo of the 1942 Webb tennis team (with David) on the wall at the entrance to the Webb gymnasium—along with other sport photos of students through the years. See

`http://www.ma.utexas.edu/CNA/files/photo7/20.html`

At Webb, David and fellow student Allen Wilson wrote a joint senior thesis solving a mathematical problem. After having some difficulties, faculty advisor Benjamin Keller encouraged them to go and talk with mathematics Professor George Birkhoff at Harvard University. David has said that Birkhoff was very helpful. This encounter may have given David the idea of going to Harvard, some years later, to study mathematics with Professor Garrett Birkhoff.

It is interesting to mention that Professor Garrett Birkhoff's father was Professor George Birkhoff—both of them were faculty members in the Mathematics Department at Harvard. The elder Birkhoff was considered, by many, to be *the* pre-eminent American mathematician of his time! Garrett received a Bachelor of Arts degree from Harvard in 1932, and, from 1933–1936, he was in the elite *Society of Fellows* at Harvard, which contained students of exceptional ability, who pursued their studies, free of any formal requirements. These Fellows were so talented that writing the traditional master's or doctoral theses would have been a waste of their time! In 1936, Garrett began teaching in the Mathematics Department at Harvard, and remained on the faculty until his death in 1996. (Whenever someone mistakenly called Garrett '*Dr* Birkhoff', he gently corrected them by saying '*Professor* Birkhoff, please').

David was in the V-12 Navy College Training Program at Webb. It was created to supplement the force of commissioned officers in the U.S. Navy, without these students having to leave their colleges. The V-12 program was a strenuous program of year-around study that thrust heavy responsibility upon these young men at an early age. They took many classes in science and mathematics, as well as physical training. The V-12 program produced educational and military

DOI: 10.1002/nla

leaders for the 50 years after World War II, including, at least, 38 admirals and 20 generals, as well as many who gained prominence in other fields—as David did!

In the Fall of 1944 (after only 3 years), David graduated from Webb with a Bachelor of Science degree in Naval Architecture, as part of the class of '*1944B*'.

4. U.S. NAVY

David enlisted in the U.S. Navy on 8 December 1942, and participated in the V-12 program at Webb, for a year and 4 months. On 1 July 1943, David started his active duty, for a period of 3 years, 8 months and 2 days. During this time, David went for naval training to the U.S.N.R. Midshipman's School at Cornell University, Ithaca, New York, for 16 weeks. On 9 March 1945, David was commissioned as an officer in the U.S. Navy. Then, Ensign Young was stationed at the David Taylor Model Basin in Washington, D.C., working as an Assistant Naval Architect. One of David's missions was aboard a Navy destroyer, the U.S.S. Fiske, which traveled to Havana, Cuba. When he was detached from active duty on 26 July 1946, he was awarded a World War II Ribbon and an American Area Campaign Ribbon. Over the years, David took correspondence courses, for his military education, as well as regular naval training. David stayed in the U.S. Naval Reserves for 20 years, and retired as a Lt Commander.

5. HARVARD UNIVERSITY

When David was discharged from the Navy, he was unsure about what to do next. Since he had always been good in mathematics, someone mentioned that he might consider a mathematical career. So, David went to Harvard to study mathematics! In 1947, David received a Master of Arts degree in mathematics, from Harvard. Then, David continued on for a doctoral degree, working for Professor Garrett Birkhoff as a Research Assistant, and then as a Research Associate. The U.S. Government was interested in David's research and supported him financially. While at Harvard, David took classes from Professor Birkhoff, on topics such as *Mathematical Physics*, among others. Also, David had classes not only in the Mathematics Department, but also in the Division of Engineering Sciences and Applied Physics at Harvard. David's first exposure to *Numerical Analysis* was when he sat in on a class, in this new area of mathematics, taught by Dr Kaiser Kunz. David did all the homework and even took the tests. In addition, David signed-up for a course in computer programming, as extra credit, and used the Mark 1 computer at the Harvard Computation Laboratory. [The Harvard Mark 1 was also known as the IBM Automatic Sequence Controlled Calculator (ASCC). It was the first large-scale automatic digital computer in the U.S.A., requiring programs on punched paper tape, which were made into loops.]

Soon after David began his doctoral work at Harvard, under the direction of Professor Garrett Birkhoff, Sir Richard Southwell, who was an expert in relaxation methods, visited Birkhoff. When David told Sir Richard about his research project, Sir Richard said: '*Any attempt to mechanize relaxation methods would be a waste of time!*' (At that time, it was widely believed that iterative methods could *not* be automated for use on computers.) Although he was discouraged, David continued his research on mathematical relaxation methods. Because he had a propensity for making errors in long tedious numerical calculations, David wanted to discover a mathematical

DOI: 10.1002/nla

procedure for use on the new computing machines, which could solve significant mathematical problems.

Finding the solutions of linear systems was an important part of many military and industrial applications. Solving such problems was done primarily by groups of women, sitting in a large room, at rows of tables, using large bulky desk calculators. They passed slips of paper around with their calculations on them. These results were monitored by a supervisor who could make local adjustments (called *local relaxation*), in an effort to speed up the convergence of the procedure.

David Monaghan Young, Jr, and Mildred Victoria Acker were married by the Reverend Thomas A. Bridges on Sunday, 9 October 1949, at St. Chrysostom's Church, Wollaston, Massachusetts. This was the beginning of their 59 years together.

Since David's thesis was due in only a few months after their marriage, David and Mildred worked together to finish it on time. David continued working on the research and Mildred, using an ink pen, hand-copied most of the mathematical symbols and equations into the three re-typed copies of the final version of his thesis. (In those days, typewriters and computers could not type-set mathematics, and photo-copying machines did not exist.) With his dissertation [1] finished, David graduated from Harvard with a PhD in Mathematics, in 1950.

In the fall of 1950, David was hired as an Instructor of Mathematics at Harvard. At the same time, Richard Varga became a first-year graduate student in the Mathematics Department. During this academic year, Richard was hired to do numerical calculations, for Professor Birkhoff and Dr Young, which were related to their U.S. Naval sponsored research on water flow past an object. The pay was $1.25 an hour, with a maximum of 8 hours per week! When the summer term of 1951 rolled around, Richard was hired to do full-time calculations on this project. Moreover, Young and Varga were assigned to be office mates. David may not have been pleased sharing an office with a *lowly* graduate student—their personalities were quite different! Nevertheless, David and Richard became good personal friends throughout their lives, and both of them became world renowned mathematicians. Both David and Richard wrote books that are frequently cited as fundamental references on iterative methods. In 1962, Richard published his first book entitled *Matrix Iterative Analysis* [2], and David published his first book entitled *Iterative Solutions of Sparse Linear Systems* [3], in 1970. David stayed focused on iterative methods throughout his career. Richard moved into approximation theory and complex function theory. Varga wrote of Young's doctoral thesis:

> 'His thesis developed an extremely deep relationship between eigenvalues of the successive overrelaxation iterative matrix and the eigenvalues of the associated Jacobi iteration matrix. This relation
>
> $$(\lambda+\omega-1)^2=\omega^2\mu^2\lambda$$
>
> is now known throughout the world as *David Young's equation*, and appears in every book on numerical analysis.'

David had considerable difficulty getting a journal to publish a paper based on his dissertation. There was a scarcity of journals that would even consider a paper on numerical analysis! Also, he had a hard time condensing it, because he found it painful to throw out results that he thought were interesting. Finally, David wrote up his thesis as a paper, and submitted it for publication. The referee, Hilda Geiringer, wrote '*This paper is far from ready for publication*'. Professor Garrett Birkhoff was determined to see it published, and urged David to rewrite the paper. After several failed revision attempts, Birkhoff suggested that David go and talk to Hilda, which was

DOI: 10.1002/nla

possible because she lived in Cambridge. (Hilda Geiringer was an Austrian trained mathematician, who taught at Wheaton Women's College in Norton, Massachusetts, during the week, and on the weekends, went home to Cambridge to be with her husband Professor Richard Edler von Mises, who taught at Harvard.) David went to her home on a Sunday afternoon, and they discussed his paper. After some additional revisions, the paper finally appeared in the *Transactions of the American Mathematical Society* [4], in 1954. David has said: '*Without Garrett Birkhoff's continued interest and encouragement, this paper would never have seen the light of day!*'. Birkhoff always considered it to be a *classic thesis*, because it established the mathematical theory for the SOR method, as well as introduced several new mathematical concepts such as *Property A* and *consistently ordered matrices*. David's thesis is still regarded as a significant mathematical achievement. Almost 50 years after it was written, Professor Gene H. Golub arranged for it to be retyped, using a computer with LaTeX (a modern mathematical type-setting system), and put it online! (See Section 13.) Golub, who was then the Chairman of the Department of Computer Sciences at Stanford University, wrote:

> 'David Young's thesis was one of the monumental works of modern numerical analysis. Thanks, David; it is a remarkable contribution and has had enormous impact for the computational and engineering communities.'

6. ABERDEEN PROVING GROUND

David's first job after graduating from Harvard was as an Applied Mathematician in the Computing Laboratory of the Aberdeen Proving Ground, Maryland, during 1950–1951. His fellow co-workers included Samuel D. Conte, Charles H. Warlick, and Mario L. Juncosa, among others. During this time, David and Mildred purchased their first new house, and had their first son, William David.

At that time, Aberdeen Proving Ground contained one of the largest collections of electronic computers in the U.S. They were employed in the Ballistics Research Laboratory (BRL), primarily for the calculation of bombing and firing tables. Some of the computers that were being used at BRL included the ENIAC, which was the first general- purpose electronic computer, the ORDVAC, which was designed by John von Neumann (who often visited Aberdeen Proving Ground), the EDVAC, which was a rotating drum computer, and a Bell Laboratory paper tape-driven computer.

David Young and Charles Warlick worked on the ORDVAC computer using Richardson's method on a 21×21 grid, which required writing a tricky computer program, at that time, because the machine had a total memory of only 1024 40-bit words with no external memory. See [5]

7. SOCIETY OF INDUSTRIAL AND APPLIED MATHEMATICS (SIAM)

David was an active member of the Society of Industrial and Applied Mathematics (SIAM), throughout his career. In 1951, he traveled by train, from the Aberdeen Proving Ground to Philadelphia, to attend SIAM's first organizational meeting. In 1953, David was in New York City on the subway with Mario Juncosa, when they happened to meet Ed Block, who was SIAM's first Managing Director. Ed told them that he was having considerable trouble finding suitable mathematical articles for the new SIAM journal. From his inside suit-coat pocket, Mario

DOI: 10.1002/nla

immediately pulled out a copy of a manuscript, which he and David had been working on, and handed it to Ed! Their article appeared in Volume 1, Issue 2 of the first SIAM journal [6].

8. UNIVERSITY OF MARYLAND

In the Fall of 1952, David took his first academic job as an Assistant Professor of Mathematics at The University of Maryland. He taught the *first* numerical analysis course given in the Department of Mathematics! After teaching for more than a year and making only about $300 per month, David went to see the chairman of the department, and asked for a raise. In lieu of more money, David was promoted to Associate Professor with tenure!

During his first academic year at Maryland, David visited the BRL to supervise Charles Warlick's work. On election night in 1952, they were working on their project using the ORDVAC computer, and, throughout the night, they kept checking both the computer results and the election results on the radio.

In the academic years 1953–54 and 1954–55, Charlie worked at The University of Maryland as a Teaching Assistant in the Department of Mathematics, and also as a Research Assistant to David. Once, Charlie took David's class of students to the David Taylor Model Basin, to see a computer in action. Charles H. Warlick was David's first master's student at The University of Maryland, and Louis W. Ehrlich was David's second master's student.

David and Mildred's second son, Arthur Earle, was born two months before they moved again.

9. LOS ANGELES

Because David and Mildred had a growing family and the aerospace industry paid more than academia, they relocated to Los Angeles, in 1955. At that time, Southern California was a center of activity in the aerospace industry, as the U.S. focused on missile and space technology. David worked as the Manager of the Mathematical Analysis Department at the Ramo–Wooldridge Corp., which later became the Space Technology Laboratory.

David regularly visited universities in the area, such as Cal Tech, USC, and UCLA. He got to know, or worked with, many of those who became well-known numerical analysts, such as Samuel D. Conte, Robert T. Gregory (who was a consultant for David's group), and many others. For example, E. Ward Cheney worked in the aerospace industry in nearby San Diego. Once, Professor George Forsythe, from Stanford University, visited David's group and brought with him a youthful Gene Golub, who had recently moved to California after finishing his PhD at The University of Illinois. David wondered why Professor Forsythe would bring, to a consulting job, someone he mistakenly thought to be a '*mere*' graduate student! Subsequently, David and Gene became good friends and colleagues for the rest of their lives! In the 1970s, during the breaks at a conference, Gene talked to David about including the *re-discovered* conjugate gradient method into his research, which David did! (Professor Golub passed away in 2007.)

Often, Bob Gregory and David Young talked about their early days in computing. While using the new computing machines during the middle of the night, they watched the lights flashing on the computer, and timed their computations with a stop watch!

DOI: 10.1002/nla

10. UNIVERSITY OF TEXAS AT AUSTIN (UT AUSTIN)

The University of Texas in Austin wanted to establish a Computation Center. Professor Robert Greenwood, and others from the Department of Mathematics, wrote to David, inviting him to come to Texas. At first, David dismissed the offer, because he considered Texas to be an '*outback*' area of the country. Eventually, he decided to go and take a look for himself. He was pleasantly surprised to find that Austin was quite a nice city, with a river, hills, and oak trees, as well as having a good university. Lou Ehrlich followed David from Maryland to California to Texas, and became his first PhD student in 1963. In the summer of 1958, David moved his family to Austin—he would spend the rest of his career there. David and Mildred's third child, Carolyn Ellen, was born in Austin.

Department of Mathematics (M)

David joined The University of Texas faculty as a Professor of Mathematics, and as the *first* Director of the Computation Center. When David moved into his office in Benedict Hall, he found that the Department of Mathematics was actually two independent departments. Faculty members were either pure mathematicians (in the R. L. Moore group), or applied mathematicians (all others). Because the pure mathematics classes were taught using the *Moore method*, once students took a pure mathematics class, they had to continue taking other pure mathematics courses, and similarly for those taking regular (applied) mathematics classes. While producing many excellent graduate students, this situation caused a number of difficulties for students at the undergraduate level. (Some of the students called this conflict between *pure* math versus *applied* math—the battle of *putrid* math and *awful* math!). Over the years, David worked extremely hard to modernize the mathematical curriculum, and to increase the number of faculty positions—resulting in the hiring of many outstanding young mathematicians.

Computation Center (COM)

In the Fall of 1958, David brought Bob Gregory to Texas to join him as a member of the mathematics faculty, and to help him set up the Computation Center—which was almost non-existent. David, Bob, and a secretary shared an office next to the computer room. The first computer was an IBM 650 Magnetic Drum Data Processing Machine, which was the world's first mass-produced computer.

During the next several years, Young and Gregory purchased new computers, expanded the staff, and designed a new building for the Center, which was built partially underground near the University tower.

In 1965, David asked Charles Warlick to move to Austin, and to help him run the expanding operations of the Computation Center.

Under David's leadership, The University of Texas not only built a new Computation Center building, but also acquired two large *supercomputer* systems—the Control Data Corp. (CDC) 1604 computer, in 1960, and the CDC 6600 computer, in 1966. Gregory was particularly interested in the CDC computers because of their long 60 bit word length. Based on his reputation, David obtained the first $400,000 grant, from the National Science Foundation (NSF), toward the purchase of the CDC 1604 computer, which was one of the first transistorized computers. The CDC 6600 supercomputer, which was one of the largest and fastest computers at that time, was purchased with the help of the *first* NSF million dollar equipment grant! The University of Texas was one of only a few universities in the world with a *supercomputer*.

DOI: 10.1002/nla

A *supercomputer* is defined as a computer that is at the forefront of the current generation of computer processing technology, with regard to its memory capacity and, in particular, its speed of doing calculations. Today, *peta-scale* supercomputers exist that are able to do one quad-trillion (1000 trillion or 10^{15}) floating-point operations per second. They are enormously faster than the early computers! In fact, the typical personal computer, in use today, is faster and has more memory than the CDC 6600!

The Computation Center was organized into three branches: the Operations Group (those who ran the machines), the Operating Systems Groups (those who wrote and maintained the software for the operating system), and the Numerical Analysis Group (those who wrote the software and documentation for the mathematical program library, as well as consulted with users). Early computers did not come with the software for the operating system, or the software for the mathematical program library!

In addition to Drs David Young, Robert Gregory, and Charles Warlick (who served as research mathematicians, as well as administrators of the Computation Center), the staff included a large number of faculty members who held, at one time or another, joint appointments with their academic departments and the Center. All were engaged in research in the application of computers to their various disciplines. There were many from the Department of Mathematics: Richard H. Bartels, E. Ward Cheney, Allen A. Goldstein, Robert T. Gregory, Yasuhiko Ikebe, David R. Kincaid, Robert E. Lynch, David D. Morrison, Larry L. Schumaker, G. W. (Pete) Stewart, III, John R. Whiteman, David M. Young, Jr, as well as, James C. Browne (Physics), Alfred G. Dale (Computer Sciences), Robert K. Lindsay (Psychology), John C. Loehlin (Psychology), Norman M. Martin (Philosophy), Terrence W. Pratt (Computer Sciences), among others.

Department of Computer Sciences (CS)

In 1966, David was among a small group of professors at The University of Texas who founded the Department of Computer Sciences. They were active users of the University computer system, and were from a variety of disciplines, as diverse as Mathematics, Chemistry, Physics, Psychology, and Philosophy, among others. At that time, the computer sciences program was a graduate-level program.

An early photo (circa 1966) of the Department of Computer Sciences faculty showed: (top row) David M. Young, Jr, Woodrow W. Bledsoe, Terrance W. Pratt, John C. Loehlin, Erna Pearson, Angus Pearson, and (first row) Robert E. Lynch, Norman Martin, Suzanne Kain Rhoads (secretary), Robert T. Gregory (Chairman), Alfred G. Dale. See

`http://www.ma.utexas.edu/CNA/files/photo3/5.html`

David was involved in hiring many outstanding faculty members, and gave those, involved in computing, joint appointments in the Computation Center. In this way, he was able to increase the number of faculty positions in both the Departments of Mathematics and Computer Sciences at The University of Texas.

Center for Numerical Analysis (CNA)

In 1970, David became the Director of the newly established Center for Numerical Analysis in order to concentrate on mathematical research, while turning management of the Computation Center over to Charles Warlick. David found office space for his new research organization in the attic of the Hogg Building next to the Computation Center.

DOI: 10.1002/nla

It is interesting to cite some of the information in the Second Annual Report of the Center for Numerical Analysis [7], from 1972, which we quote:

'The research was carried on by the senior members of the staff and by graduate students working under their direction. There were nine senior people, with faculty appointments in either Mathematics (M) or Computer Sciences (CS): Director David M. Young (M, CS), Associate Director Robert T. Gregory (M, CS), John R. Cannon (M), E. Ward Cheney (M), James W. Daniel (M), Yasuhiko Ikebe (CS), George G. Lorentz (M), Larry L. Schumaker (M). Senior people served on the staff: Jo Ann Howell (CS), David R. Kincaid (M), Marie-Jeanne Munteanu (M, visitor), G. W. Stewart (M, CS). The work of the senior staff was supported by the technical personnel: John Dauwalder (Head of Consultation), Vitalius Benokraitis, Mrs Kiho Kim, George Kontos. In addition, the office was staffed by Mrs Dorothy Baker and Mrs Barbara Allen.'

'The numerical analysis research activity received substantial support from the U.S. Government, including the NSF (Young, Gregory, Stewart, Ikebe, Cannon, Lorentz), Army Research Office, Durham (Young, Gregory), Air Force, Office of Scientific Research (Schumaker, Cheney), Office of Naval Research (Daniel, Stewart).'

One of the early CNA software projects was the '*National Activity for Testing Software* (*NATS*)'. Researchers (from Argonne National Laboratory, University of Texas, and Stanford University) performed the certification of the EISPACK software package, for computing eigenvalues and eigenvectors of matrices. Originally, *NATS* stood for **N**SF, **A**rgonne, **T**exas, and **S**tanford.

In the mid 1970s, the CNA moved to offices in the new physics–mathematics–astronomy building, which was named the R. L. Moore (RLM) Hall, after the mathematician Robert Lee Moore. For many years, the CNA occupied part of the top (13th) level of the math wing.

Some of those who taught at The University of Texas at Austin, and were associated with the CNA, were Randolph Bank, Andrew Sherman, David Gay, Linda Hayes, Ann Elster, among others. Frequent visitors were Owe Axelsson, Eugene Wachspress, and many others. Some of the secretaries, who worked for Dr Young in the CNA, included: Dorothy Baker, Barbara Allen, Sheri Brice, Katherine Mueller, and Katy Burrell.

Institute for Computational Engineering and Sciences (*ICES*)

Throughout his career, David was actively involved in joint research projects with members of the College of Engineering and, in particular, with Professor Graham Carey along with Professor Tinsley Oden and others. David was a founding member of, what is now, the Institute for Computational Engineering and Sciences. Beginning in early 1993, David served as a member of an inter-departmental committee that established the *Computational and Applied Mathematics* (*CAM*) graduate program. Also, David taught courses in the CAM program.

Professorship

In 1983, David was awarded a distinguished professorship: the Ashbel Smith Professor of Mathematics and Computer Sciences. For health reasons, David retired in 1999, and was an Emeritus Professor of Mathematics and Computer Sciences until his death in 2008.

DOI: 10.1002/nla

Research

David has written approximately 200 research papers, and is the author of three books. The first book, *Iterative Solution of Large Linear Systems* [3], was devoted to the basic theory of iterative methods, such as variants of the SOR method, among others. The second book, with Robert Todd Gregory, *A Survey of Numerical Mathematics* [8, 9] (in two volumes), was used in a year-long undergraduate numerical analysis course. The third book, with Louis A. Hageman, *Applied Iterative Methods* [10], was a graduate-level monograph on the mathematical theory behind the iterative algorithms in the ITPACK software.

Software

Since the 1970s, David has collaborated with David R. Kincaid on the ITPACK project. Their focus was on iterative algorithms research, and on the development of research-oriented mathematical software. Since the performance of SOR-type methods were extremely sensitive to the choice of relaxation parameters, this uncertainty discouraged the use of iterative methods, as opposed to direct methods. Young's group developed automatic (or *adaptive*) iterative algorithms and incorporated them into the ITPACK software. From various versions of ITPACK to Nonsymmetric Preconditioned Conjugate Gradient (NSPCG), many software packages were developed with the capability of handling both symmetric and nonsymmetric systems. Over time, the emphasis of the software was increasingly on the best use of advanced computer architectures, from scalar to vector to parallel to distributed computer systems. For each evolution in the computer architecture, new versions of the software packages were written. Many of the adaptive iterative algorithms, used in the ITPACK software, were developed by David Young and Louis Hageman, working with students and collaborators. They can be found in various CNA reports, and the Hageman–Young book [10]. These software packages were written by David Kincaid, Thomas Oppe, Wayne Joubert, Tzun-Zee Mai, among others. David Young, Louis Hageman, Cecilia Jea, and others developed the generalized conjugate gradient acceleration procedures ORTHODIR, ORTHOMIN, and ORTHORES.

Honors and awards

Over the years, David received numerous awards and honors. In 1983, he was elected as a Fellow of the American Association for the Advancement of Science. In 1990, David was given an award for '*Outstanding Contributions to Computer Science*' by the Special Interest Group on Computer Science Education of the Association of Computing Machinery (ACM). For many years, David served on national and international boards and committees, such as a member of the Board of Trustees for the Argonne Universities Association at the Argonne National Laboratory.

David has been honored with special issues of research journals dedicated to him, as well as book dedications—some of these books are in foreign languages. For example, a special journal issue [11], edited by Owe Axelsson and Yuri A. Kuznetsov, was published on the occasion of David's 70th birthday. Also, the various editions of the book *Numerical Mathematics and Computing* [12] by Cheney and Kincaid were dedicated to David. Moreover, conferences were held in his honor, with the conference proceedings being published. In particular, a conference on iterative methods was held in Austin, in October of 1988, on the occasion of David's 65th birthday. The invited talks were published in a book edited by David Kincaid and Linda Hayes [13]. This was one of the *first* in a series of conferences exclusively devoted to iterative methods! Then again in October of

DOI: 10.1002/nla

1998, on the occasion of David's 75th birthday, another conference on iterative methods was held at The University of Texas at Austin. The proceedings were published in a book, edited by David Kincaid and Anne Elster [14]. Now these conferences are held every 2 or 3 years, sponsored by the *International Association for Mathematics and Computer Simulation* (*IMACS*), and are called the *International Symposium on Iterative Methods in Scientific Computations*. (During the 1988 conference, Dr Charles Warlick mentioned to Professor Garrett Birkhoff that he was David's first student. Professor Birkhoff smiled and replied: '*No, I was!*').

Over the years, David's research was supported by various federal grants, but especially the NSF, the Department of Energy, and the U.S. Army. Many millions of dollars in grants were obtained by David. This money helped purchase computers, and to partially support David, as well as other faculty members, staff, graduate students, and researchers. David involved his graduate students in his research, and incorporated the research into his graduate courses. Frequently, the research lead to theses or dissertations for his students.

Teaching

David was a well-liked teacher and mentor. Frequently, visiting professors to UT Austin sat-in on David's graduate classes, as well as did students from other academic departments, such as from engineering. David taught graduate courses that were jointly listed in the Department of Mathematics, the Department of Computer Sciences, and the CAM program. Some of the graduate classes that David regularly taught were *Numerical Treatment of Differential Equations* and *Numerical Solution of Elliptic Partial Differential Equations*, as well as undergraduate mathematics classes such as *Survey of Numerical Techniques* and *Matrices and Matrix Calculations*.

Students

Dr Young supervised 14 PhD students, (all at The University of Texas at Austin): Louis W. Ehrlich (1963), Thurman G. Frank (1966), Alvis E. McDonald (1970), Jerry C. Webb (1970) with co-supervisor John Whiteman, David Kincaid (1971), Vitalius J. Benokraitis (1974), Linda J. H. Hayes (1977) with co-supervisor Mary Wheeler, Cecilia Kang Chang Jea (1982), Tsun-Zee Mai (1986), Thomas Charles Oppe (1989) with co-supervisor David Kincaid, Wayne David Joubert (1990), Bi Roubolo Vona (1992), Shengyou Xiao (Jason Shaw) (1994) with co-supervisor Kamy Sepehnioori, Jen-Yuan Chen (1996).

Dr Young supervised 25 master's degree students (all at The University of Texas at Austin, except for the first two, which were at The University of Maryland): Charles H. Warlick (1955), Louis W. Ehrlich (1956), Robert A. Sibley (1959), Jessee J. Stephens (1961), W. P. Cash (1961), M. C. Scully (1962), Mary B. Fanett (1963), Charles A. Shoemake (1964), W. P. Champagne (1964), W. G. Poole (1965), James A. Downing (1966), Alkis Mouradoglou (1967), Harold D. Eidson (1969), Belinda M. Wilkinson (1969), Tran Phien (1972) with co-supervisor David Kincaid, Linda J. H. Hayes (1974), Janis Anderson (1983), Ru Huang (1983) with co-supervisor David Kincaid, Reza Oraiee Abbasian (1984), Vona Bi Roubolo (1985), Florian Jarr'e (1986), Malathi Ramdas (1990) with co-supervisor David Kincaid, Maryam Askar-Tehrany Purvis (1992) with co-supervisor David Kincaid, Asha Nallana (1995) with co-supervisor David Kincaid, Chih-Chuan Chen (1995) with co-supervisor David Kincaid.

In 1963, David supervised Mary Fanett Wheeler's master's thesis. She married John Wheeler—a student she had meet in David's class. Mary obtained a PhD at Rice University, and was on the Rice faculty. Mary and John, who worked for Exxon Research, lived in Houston for many years

DOI: 10.1002/nla

before coming back to Austin in 1995. Mary brought her entire research group of a dozen or more researchers to The University of Texas at Austin.

In 1977, Linda J. Hayes wrote her PhD thesis under the co-supervision of David Young and Mary Wheeler of Rice University. Linda became the first female faculty member in the College of Engineering at The University of Texas at Austin.

11. ACTIVITIES

David lived an extremely active life until his last decade. Most days, he taught classes, discussed research with his students, went to meetings with fellow faculty members, attended seminars, did administrative work, went out to eat with colleagues or friends, played tennis, went home to his family, and did research far into the night (after everyone had gone to bed).

David was a world traveler who was invited to give talks at international conferences. Many times, David spoke at conferences in England, around the time of the Wimbledon Tennis Tournament, which he was then able to attend. In fact, before Wimbledon became an open tennis tournament, David applied to play tennis in the amateur ranks! David used to jokingly say that he wanted to have written on his tombstone '*Was considered for Wimbledon*'. On these trips, he stopped over in Boston to work with Professor Garrett Birkhoff at Harvard, and to visit Professor Martin Schultz at Yale, as well as giving lectures and taking the time to see relatives in the Boston area.

While attending conferences, David was always friendly and generous with his time in talking with graduate students, as well as giving them advice and counsel. Occasionally, David would take a personal interest in a graduate student, and he would stay in touch by letters and email. Often he would offer suggestions on ways of resolving whatever mathematical or academic problems they might be having. Many of his friends, in the scientific computing community, can recall first meeting David at a conference.

David was a '*big*' man, both physically and in his profession, who had a huge impact on the lives of his students, as well as on many of his colleagues and friends. David was an inspiring teacher and a fine gentleman, who was an international leader of his era.

12. FAMILY

In 1974, David's son William graduated from MIT with a Bachelor of Science degree in aerospace engineering, and went into the U.S. Air Force, retiring as a Major after 20 years. Currently, he is an international pilot with Delta Airlines. William and his wife, Linda Sue, live in Phoenix, Arizona. They are the parents of John Robert and Sara Noelle.

David's son Arthur finished high school and enlisted in the U.S. Army for 2 years. Afterwards, he went to Trinity University in San Antonio, Texas, and obtained a Bachelor of Science degree in business, in 1979. Next, Arthur obtained a Master of Business Administration degree, from The University of Texas at Austin, and worked as a Certified Public Accountant. In 2002, Arthur received a Doctor of Philosophy degree in business administration from Texas Tech University, in Lubbock, Texas. Currently, Arthur is teaching at Fort Hays State University in Hays, Kansas.

David's daughter Carolyn graduated from The University of Texas at Austin, with a Bachelor of Science degree in education, in 1981. Currently, she is living with Mildred in Austin, Texas.

David's sister Christine Y. Sorenson, and her son Dr David Wendell Sorenson, live in Quincy, Massachusetts. Christine is an artist who graduated from New England School of Art. Her daughter

DOI: 10.1002/nla

Sylvia (Sorenson) Newell lives with her family in Schenectady, New York. David Sorenson has a PhD from Queens College, Cambridge, England.

13. MORE INFORMATION

Additional information on Professor David M. Young's career can be found at:

`http://www.ma.utexas.edu/CNA/DMY/`

For more details on the history of scientific computing, including iterative methods, see:

`http://history.siam.org/` `http://ieeeghn.org/`

Some of Dr. Young's signification journal publications are [4–6, 15–32].

14. YOUNG INSTRUCTORSHIP

To honor his memory, The University of Texas at Austin has established the *David M. Young, Jr, Instructorship in Computational and Applied Mathematics*, to support young postdoctoral researchers. Those wishing to contribute to this endowment may send donations to:

University of Texas at Austin
College of Natural Sciences—Office of Dean
1 University Station G2500
Austin, TX 78712–0548, U.S.A.

`giving@cns.utexas.edu` (512) 471–3299 `http://cns.utexas.edu/invest/`

ACKNOWLEDGEMENTS

Many thanks to Mildred V. Young, William D. Young, Dr Arthur E. Young, Carolyn E. Young, Christine E. Young Sorenson, Dr David W. Sorenson, and Dr E. Ward Cheney, for assistance with this paper, as well as the Department of Mathematics and the Archives of American Mathematics (AAM) in the Dolph Briscoe Center for American History—both at The University of Texas at Austin.

REFERENCES

1. Young DM. Iterative methods for solving partial difference equations of elliptic type. *Ph.D. Thesis*, Harvard University, Mathematics Department, Cambridge, MA, U.S.A., May 1950.
2. Varga RS. *Matrix Analysis*. Phentice-Hall: Englewoods Cliffs, NJ, 1962. ((2nd edn). Springer Series in Computational Mathematics, vol. 27. Springer: Berlin, Heilderberg, New York, 2000).
3. Young DM. *Iterative Solution of Large Linear Systems*. Computer Science and Applied Mathematics Series. Academic Press: New York, NY, U.S.A., 1970. (Republished by Dover, Mineola, NY, U.S.A., 2003.)
4. Young DM. Iterative methods for solving partial difference equations of elliptic type. *Transactions on American Mathematical Society* 1954; **76**:92–111.
5. Young DM, Warlick CH. On the use of Richardson's method for the numerical solution of Laplace's equation on the ORDVAC. *Memorandum Report 707*, Ballistic Research Laboratories, Aberdeen Proving Ground, MD, U.S.A., 1953.

6. Juncosa ML, Young DM. On the order of convergence of solutions of a difference equations to a solution of the diffusion equation. *Journal of Society Industrial and Applied Mathematics* 1953; **1**:111–135.
7. Young DM, Gregory RT. *Second Annual Report CNA-B2*, Center for Numerical Analysis, University of Texas, Austin, TX, 31 August 1972.
8. Young DM, Gregory RT. *A Survey of Numerical Mathematics*, vol. I. Addison-Wesley: Reading, MA, U.S.A., 1972. (Republished by Dover, Mineola, NY, U.S.A., 2003.)
9. Young DM, Gregory RT. *A Survey of Numerical Mathematics*, vol. II. Addison-Wesley: Reading, MA, U.S.A., 1973. (Republished by Dover, Mineola, NY, U.S.A., 2003.)
10. Hageman LA, Young DM. *Applied Iterative Methods*. Computer Science and Applied Mathematics Series. Academic Press: New York, NY, U.S.A., 1981. (Republished by Dover, Mineola, NY, U.S.A., 2003.)
11. Axelsson O, Kuznetsov YA. *Numerical Linear Algebra with Applications* 1995; **2**(5):399–486.
12. Cheney W, Kincaid D. *Numerical Mathematics and Computing* (6th edn). Brooks/Cole Engage Learning: Florence, KY, 2008.
13. Kincaid DR, Hayes LJ (eds). *Iterative Methods for Large Linear Systems*. Academic Press: NY, 1989.
14. Kincaid DR, Elster A (eds). *Iterative Methods in Scientific Computing IV*. IMACS Series in Computing and Applied Mathematics, vol. 5. IMACS: New Brunswick, NJ, 1999.
15. Birkhoff G, Young DM. Numerical quadrature of analytic and harmonic functions. *Journal of Mathematical Physics* 1950; **29**:217–221.
16. Young DM. An error bound for the numerical quadrature of analytic functions. *Journal of Mathematical Physics* 1952; **31**:42–44.
17. Young DM. On Richardson's method for solving linear systems with positive definite matrices. *Journal of Mathematical Physics* 1954; **32**:243–255.
18. Young DM. ORDVAC solutions of the Dirichlet problem. *Journal of the Association of Computing Machinery* 1955; **2**(3):137–161.
19. Young DM. The numerical solution of elliptic and parabolic partial differential equations. In *Survey of Numerical Analysis*, Todd J (ed.). McGraw-Hill: New York, NY, U.S.A., 1962; 380–438.
20. Birkhoff G, Varga RS, Young DM. Alternating direction implicit methods. In Alt F, Rubinoff M (eds). *Advances in Computers*, Academic Press: New York, NY, U.S.A., 1962; 189–273.
21. Young DM, Wheeler MF. Alternating direction methods for solving partial difference equations. In Ames WF (ed.). *Nonlinear Problems of Engineering*, Academic Press: New York, NY, U.S.A., 1964; 220–246.
22. Young DM. Convergence properties of the symmetric and unsymmetric successive overrelaxation methods and related methods. *Mathematics of Computations* 1970; **24**(112):793–807.
23. Young DM. A bound for the optimum relaxation factor for the successive overrelaxation method. *Numerische Mathematik* 1970/1971; **16**:408–413.
24. Young DM. On the consistency of linear stationary iterative methods. *SIAM Journal on Numerical Analysis* 1972; **9**(1):89–96.
25. Young DM. Generalizations of property A and consistent ordering. *SIAM Journal on Numerical Analysis* 1972; **9**(3):454–463.
26. Young DM. Second-degree iterative methods for the solution of large linear systems. *Journal of Approximation Theory* 1972; **5**:137–148.
27. Young DM. A survey of modern numerical analysis. *SIAM Review* 1973; **15**:503–523.
28. Young DM. On the accelerated SSOR method for solving large linear systems. *Advances in Mathematics* 1977; **23**(3):215–271.
29. Young DM, Jea KC. Generalized conjugate gradient acceleration of non-symmetrizable iterative methods. *Linear Algebra and Its Applications* 1980; **34**:159–194.
30. Young DM, Kincaid DR. The ITPACK package for large sparse linear systems. In Schultz M (ed). *Elliptic Problem Solvers*, Academic Press: New York, NY, U.S.A., 1981; 163–185.
31. Young DM. A historical overview of iterative methods. *Computer Physics Communications* 1987; **53**:1–17.
32. Young DM. Garrett Birkhoff and applied mathematics. *Notices of the American Mathematics Society* 1997; **44**(11):1446–1450.

CONTENTS

VOLUME 17, ISSUE NO. 5 October 2010

Special Issue:

Dedicated to the memory of David M. Young, Jr.

Guest Editors: Owe Axelsson and David R. Kincaid

PREFACE: O. Axelsson and D. R. Kincaid 741

The life and times of Dr David M. Young, Jr: D. R. Kincaid, R. S. Varga and C. H. Warlick 743

A new multilevel algebraic preconditioner for the diffusion equation in heterogeneous media: Y. Kuznetsov and A. Prokopenko 759

Efficient algorithms for multiscale modeling in porous media: M. F. Wheeler, T. Wildey and G. Xue 771

Preconditioning of matrices partitioned in 2 × 2 block form: Eigenvalue estimates and Schwarz DD for mixed FEM: O. Axelsson and R. Blaheta 787

Incremental incomplete LU factorizations with applications: C. Calgaro, J.-P. Chehab and Y. Saad 811

Second-order treatment of the interface of domain decomposition method for parabolic problems: Y. Jun and T.-Z. Mai 839

Condition number bounds and mesh quality: L. Branets and G. F. Carey 855