Symposium on Gene Golub's Legacy:
Matrix Computations – Foundation and Future

A teacher affects eternity; he can never tell where his influence stops.
— Henry Adams

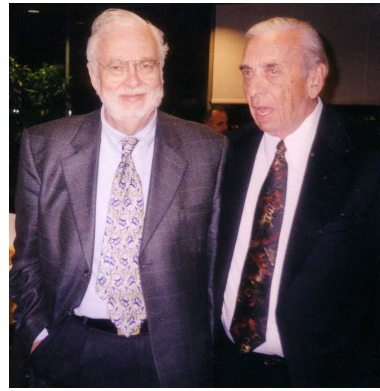Stanford University
Terman Auditorium
March 1, 2008

Hosted by
Institute for Computational and Mathematical Engineering
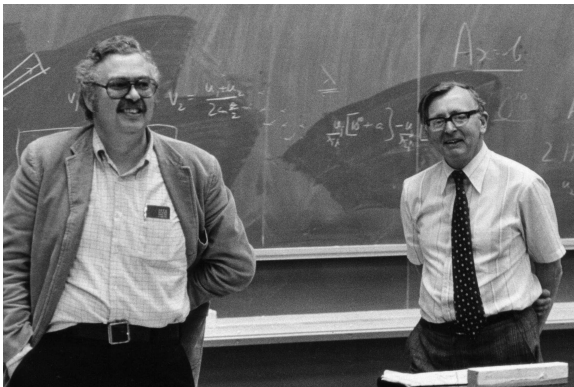and **Department of Computer Science**

A young Gene

Gene with his brother Alvin

Wolfgang Poppelbaum, Gene, and A. S. Douglas, in front of the ILLIAC computer, University of Illinois, circa 1955

Gene with mother Bernice and brother Alvin

Gene with Jim Wilkinson and $Ax = b$

Gene with Alston Householder

Emilie Haynsworth, Alan Hoffman, Olga Taussky, and Gene, Gatlinburg, Tennessee, 1964

Bill Miller, Ed Feigenbaum, John McCarthy, Gene, Don Knuth, and Nils Nilsson at Stanford Computer Science's 40th anniversary, April 2006

Serra House volleyball, Stanford, 1977
Back: Randy LeVeque, Jim Wilkinson, Ken Bube,
Gene, Bill Coughran, Walter Gander,
Frank Luk, Eric Grosse
Front: Nick Trefethen, Steve Nash, Marsha Berger,
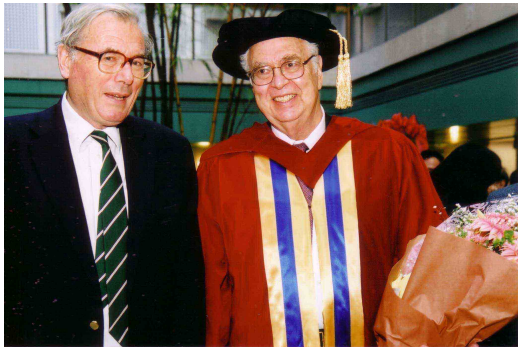Hakan Ekblom, Petter Bjørstad, Steve Leon

Gene with families of
Walter Gander and Jack Dongarra

Beresford Parlett, Gene, and Dan Boley,
Berkeley, 1977

Gene dancing with Nancy Nichols at the
Sparse Matrix Meeting in
Saint-Girons, France, June 2003

Gene receiving his 10th honorary degree
from the Hong Kong Baptist University,
with Mike Powell, December 2002

Gene hosting Joe Keller, Tony Jameson,
SCCM seminar speaker Peter Lax, and
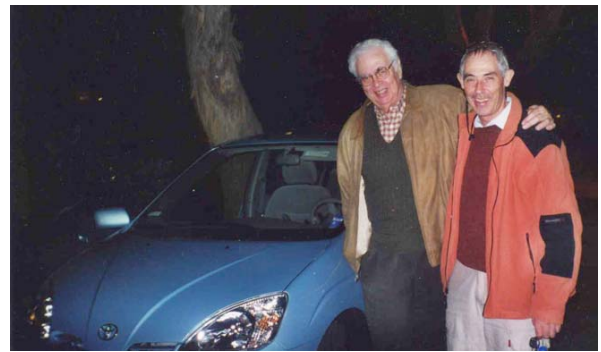students at his house, October 28, 2003

Gene officiating at Ofer and Dona Levi's
wedding in his house garden, September 27, 2003

Gene hosting a party at home with
Anita and Ingram Olkin, June 2006

Gene's Lexus license plate

Gene with Mike Saunders and
Mike's new Prius, 2004

Gene appearing rosy

Gene with Lawrence and Leah Friedman

Former students from Serra House era celebrating
Gene's 60th birthday, Minneapolis, 1992

SCCM faculty and students celebrating
Gene's 70th birthday, February 2002

Scholars from all over the world celebrating Gene's 75th birthday and
50th anniversary of George Forsythe's arrival at Stanford, March 29–31, 2007

Time	Event
8:00– 8:45	Continental breakfast

Welcome and opening remarks

8:45– 9:00	**Peter Glynn**, Director of iCME, Stanford University **William Dally**, Chair of Computer Science Department, Stanford University

First session	Chair: Chen Greif, University of British Columbia
9:00– 9:05	Mini-Memory, **Nancy Nichols**, University of Reading
9:05– 9:10	Mini-Memory, **Gilbert Strang**, Massachusetts Institute of Technology
9:10– 9:30	**Charles Van Loan**, Cornell University *50/50, 20/20, and other golden ratios: Remembering a favorite collaboration*
9:30–10:00	**Howard Elman**, University of Maryland *Inner-outer iterations and preconditioners for constrained linear systems of equations*
10:00–10:20	**Margaret Wright**, New York University *Serra House as a transformation: Structure, stability, and updating*
10:20–10:25	Mini-Memory, **Sou-Cheng Choi**, Oracle Corporation

Second session	Chair: James Lambers, Stanford University
11:00–11:05	Mini-Memory, **Julia Olkin**, California State University
11:05–11:10	Mini-Memory, **Ingram Olkin**, Stanford University
11:10–11:30	**Walter Gautschi**, Purdue University *Gene Golub's fascination with matrices, moments, and quadrature*
11:30–12:00	**Michele Benzi**, Emory University *Decay results for functions of band matrices, the HSS preconditioner, and saddle point problems: Some highlights from a collaboration*
12:00–12:20	**Jack Dongarra**, University of Tennessee, ORNL, and University of Manchester *One of Gene's hobbies: Building a scientific computing community (Netlib and NA-Net)*

Third session	Chair: Michael Saunders, Stanford University
2:00– 2:05	Mini-Memory, **James Varah**, University of British Columbia
2:05– 2:10	Mini-Memory, **Grace Wahba**, University of Wisconsin
2:10– 2:40	**Tamara Kolda**, Sandia National Laboratories, Livermore *Efficient computations with tensors*
2:40– 3:10	**Lek-Heng Lim**, University of California *Numerical multilinear algebra: From matrices to tensors*
3:10– 3:30	**Sepandar Kamvar**, Google Inc. *$n = 8$ billion. Gene Golub and the mathematics of the World Wide Web*

Fourth session	Chair: Dianne O'Leary, University of Maryland
4:00– 4:05	Mini-Memory, **Petter Bjørstad**, University of Bergen
4:05– 4:10	Mini-Memory, **Daniela Calvetti**, Case Western Reserve University
4:10– 4:40	**Zhaojun Bai**, University of California *Bilinear forms and secular equations in electronic structure calculations*
4:40– 5:00	**Chen Greif**, University of British Columbia *Gene speaks for himself: Excerpts from an interview*
5:00– 5:15	Tributes from participants

Abstracts

Bilinear forms and secular equations in electronic structure calculation

Zhaojun Bai, University of California, Davis

Bilinear forms and secular equations appear in many scientific and statistical computing problems. Gene conceptualized the idea of bilinear form and secular equation computing, and worked on its theoretical and numerical aspects over three decades. In this talk, we will discuss the continual and compelling need of large-scale bilinear form computing in modern electronic structure calculations of materials and nanostructures.

Decay results for functions of band matrices, the HSS preconditioner, and saddle point problems: Some highlights from a collaboration

Michele Benzi, Emory University

In this talk I will describe some of the results of my collaboration with Gene Golub. In the first part of my talk I will explain how our attempt to compute preconditioners for SPD matrices using Gene's method of matrix moments led to a theory of exponential off-diagonal decay in the entries of analytic functions of banded Hermitian matrices. This theory has recently found application in quantum information processing. Some recent extensions and further applications of the theory will be briefly mentioned. In the second part of the talk I will describe our work on the use of the Hermitian/Skew-Hermitian Splitting (introduced by Bai, Golub, and Ng) as a preconditioner for saddle point problems.

One of Gene's hobbies: Building a scientific computing community (Netlib and NA-Net)

Jack Dongarra, University of Tennessee, Oak Ridge National Laboratory, and University of Manchester

In addition to Gene's contributions to matrix computation he was influential in Netlib, the NA Net and the digest. These systems were created in 1984 to facilitate quick distribution of public domain software routines and community interaction. The Numerical Analysis Net (or "NA Net") began as a simple file of contact information for numerical analysts and evolving into an email forwarding service for the community. It soon evolved to support a regular electronic mail newsletter, and eventually an online directory service. This talk will look at these systems and Gene's influence on them.

Inner-outer iterations and preconditioners for constrained linear systems of equations

Howard Elman, University of Maryland, College Park

The numerical solution of constrained linear systems of equations such as the Stokes and linearized Navier-Stokes equations entails "inner" iterations for certain subsidiary problems such as the discrete Poisson and convection-diffusion equations. We discuss the use of inner iterations for the subproblems, and we examine how this general methodology is affected by acceleration strategies such as Richardson and conjugate gradient iteration. We then discuss the connections between inner iteration and preconditioning and show that these connections lead to the development of efficient preconditioners for the constrained problems arising in models of incompressible flows.

Gene Golub's fascination with matrices, moments, and quadrature

Walter Gautschi, Purdue University

One of the early highlights in Golub's work is the now classical Golub-Welsch characterization of Gaussian quadrature rules in terms of eigenvalues and eigenvectors of a tridiagonal matrix. Some personal recollections regarding the discovery of this and related results will be offered. It is here where moments come in, and where Golub's interest in moments and generalized moments, as well as in orthogonal polynomials and quadrature, took off. What he has done with these tools in the field of linear algebra will be briefly summarized.

Gene Speaks for himself: Excerpts from an interview

Chen Greif, University of British Columbia

The Milestones book of Gene's selected works was completed and published just in time for the Stanford50 meeting, March 2007. One item that we editors (Raymond Chan, Dianne O'Leary and I) wanted to include was a biography of Gene. During the course of 2006 Gene and I met three times, twice at Stanford and once in Vancouver, and taped an interview several hours long. Gene talked with passion and detail about his life and his work, and the tapes are fascinating and full of interesting stories. In this talk we will hear excerpts from the interview.

$n = 8$ billion.
Gene Golub and the mathematics of the World Wide Web

Sepandar Kamvar, Google Inc.

From 2000–2003, Gene and I collaborated on ways to compute web search rankings fast enough to enable personalized search, which amounted to a web-scale eigenvector approximation for every user of a search engine. I will discuss the collaboration and use it as a window on Gene's far reaching impact on the information industry.

Efficient computations with tensors

Tamara Kolda, Sandia National Laboratories, Livermore

In this talk I will discuss some work that came out of the Workshop on Tensor Decompositions, which was co-organized by Gene Golub. The focus will be on efficient computations with tensors. We mention the Tensor Toolbox for MATLAB, which is an object-oriented library of methods for dense, sparse, and structured tensors. We discuss the critical operations in two higher-order generalizations of the matrix SVD: the CANDECOMP/PARAFAC (CP) and Tucker decompositions. This talk includes joint work with Brett Bader (Sandia National Labs) and Jimeng Sun (IBM).

Numerical multilinear algebra: From matrices to tensors

Lek-Heng Lim, University of California, Berkeley

Gene had often lamented that linear algebra, as taught in math departments, and CS237A, his famous course on numerical linear algebra, bore almost no relation to each other. One reason is that in math, linear *algebra* is regarded as a topic in algebra and is mostly about what could be deduced from the axiomatic definitions of fields and vector spaces. Notions like conditioning, least squares, norms, orthogonality, SVD, though central to numerical linear algebra, do not extend to arbitrary fields and are relegated to a secondary status. Another difference, as Gene also liked to emphasize, is the pivotal role played by matrices. Many mathematicians prefer coordinate-free objects and regard matrices with disdain. But while matrices could represent linear operators with respect to some bases, they could also represent bilinear forms, order-2 tensors, graphs, metrics, correlations, hyperlink structures, DNA microarray measurements, movie ratings by viewers—many of these make little sense when viewed as an operator. When one realizes that a matrix is not necessarily a coordinate representation of a linear operator, and is contented with results valid only over the real and complex fields, linear algebra becomes enormously more interesting. In similar spirit, we will examine the prospects of a subject we call "numerical multilinear algebra", which is to multilinear algebra what numerical linear algebra is to linear algebra.

50/50, 20/20, and other golden ratios: Remembering a favorite collaboration

Charles Van Loan, Cornell University

Working with Gene on GVL1, GVL2, and GVL3 was a defining experience; an occasion to witness up close the breadth and beauty of the matrix computation field. During this period there was a 1:1 correspondence between my 2AM revisions and Gene's missed airplane connections! Finishing up GVL4 without Gene has been a different experience, prompting me to share book-related thoughts on collaboration, research vision, and the metaphor of 1.61803398874989 . . . .

Serra House as a transformation: Structure, stability, and updating

Margaret Wright, New York University

Among the recurrent themes in Gene's work were (problem) structure, (numerical) stability, and (low-rank) updates. These concepts can be extended to an interpretation of Serra House as a life-changing transformation experienced for many years by a sequence of students and visitors at Stanford. I will propose some lighthearted connections between Gene's favorite topics and an a posteriori analysis of time spent at Serra House.

Program Committee:
Chen Greif (co-chair), University of British Columbia
Dianne O'Leary (co-chair), University of Maryland
Sou-Cheng (Terrya) Choi, Oracle Corporation
Peter Glynn, Stanford University
James Lambers, Stanford University
Michael Saunders, Stanford University

Memorial websites:
Symposium on Gene Golub's Legacy, http://icme.stanford.edu/golub_symposium_2008
Remembrances in Celebration of Gene Golub, http://icme.stanford.edu/golub_celebration_2008
Remembering Gene Golub Around the World, http://www.cs.nyu.edu/overton/genearoundtheworld
Gene H Golub Memorial, http://genehgolub.blogspot.com
History links, http://www.cse.uiuc.edu/golub/links.html

IN GENE'S WORDS

I am an Applied Wilkinsonian.

*I always feel there is just one more problem
around the corner that we have to solve.*

*I'm amazed where I stand today . . . .
I just sort of . . . meandered into the kinds of
world that I am in . . . .
I don't feel I am particularly talented; I just feel
that I have been fortunate . . . .
At Illinois they had a computer so I just slipped
into the right place at the right time . . . .
From the academic side I really have achieved
much more than I ever would have dreamt of.
I didn't even know what to dream.*

Photos:
Mike Botchev, Sou-Cheng (Terrya) Choi, Jack Dongarra, Marie-Louise Gander, Walter Gander, Hector Garcia-Molina,
Gene Golub's collection, Michael Heath, P. M. Kroonenberg, Gio Wiederhold, World Scientific Publishing Company

LATEX2e Program:
Sou-Cheng (Terrya) Choi and Michael Saunders