

Dec., 2017.

Anne Greenbaum  
University of Washington  
Applied Mathematics Department  
Box 353925  
Seattle, WA 98195  
Phone: (206) 543-1175, email: greenbau@amath.washington.edu

## **EDUCATION:**

B.S. : University of Michigan, 1974. (Mathematics, Philosophy)  
M.A. : University of California, Berkeley, 1978. (Mathematics)  
Ph.D. : University of California, Berkeley, 1981. (Mathematics)

Thesis advisors: Beresford Parlett and Paul Concus.  
Thesis title: "Convergence Properties of the Conjugate Gradient  
Algorithm in Exact and Finite Precision Arithmetic"

## **EMPLOYMENT:**

Sept., 2009 - University of Washington. Applied Math Dept.  
present Professor.

Sept., 1997 - University of Washington. Mathematics Dept.  
Sept., 2009 Professor.

Feb., 1986 - Courant Institute of Mathematical Sciences,  
Sept., 1997 New York University. Research Professor.

June, 1974 - Lawrence Livermore National Laboratory.  
Jan., 1986 Mathematician.

Sept., 1979 - University of California, Berkeley.  
June, 1980 Mathematics Dept. Teaching Assistant.

## **AWARDS:**

SIAM Fellow, 2015.

B. Bolzano Honorary Medal for Merit in the Mathematical Sciences, Academy of Sciences of the Czech Republic, 1997.

SIAM Activity Group on Linear Algebra Award for Outstanding Paper in Applicable Linear Algebra during 1991–1993.

## **GRADUATE STUDENTS SUPERVISED:**

Trevor Caldwell and Kenan Li, current PhD students.

Alan Chen, PhD in Applied Math, July, 2014.

Daeshik Choi, PhD in Math, July 2013.

Eric Machorro, PhD in Applied Math, Jan., 2010.

Miguel Gomez, PhD in Applied Math, Mar. 2008.

Shaminoo Kapoor, M.S. in Applied Math, June, 2011.

Angelo Polo, M.A. in Math, June, 2007.

Juliet Andersen, M.S. in Math, Aug., 2005.

Geping Liu, M.S. in Math, June, 2002.

Christina Merten, M.S. in Math, Aug., 2002. Thesis: *Multigrid Methods and their Application to the Variable Coefficient Poisson Problem.*

Chris Green, M.S. in Math, Aug., 2001. Thesis: *Connections between Lanczos Iteration and Orthogonal Polynomials.*

Lei Tang, M.S. in Math, Aug., 2001.

Minerva Catral, M.S. in Math, Aug., 2000. Thesis: *A Conditioning Function for the Global Error Bounds on Numerical Solutions to ODE's.*

## **SELECTED PROFESSIONAL ACTIVITIES:**

Co-organizer (with Mark Embree and Michael Overton) AIM workshop on Crouzeix's conjecture. To occur in summer 2017.

Program Committee, 2009 SIAM Conference on Applied Linear Algebra.

Program Committee, Harrachov 2007 meeting on Computational Methods and Applications. Editor of special issue of ETNA devoted to papers from Harrachov meeting.

Vice-president, SIAM Activity Group on Linear Algebra. Chair of Committee to award Outstanding Paper in Applicable Linear Algebra prize for papers published between Jan., 2003 and Dec., 2005.

## **SELECTED RECENT TALKS:**

- “Some Extensions of the Crouzeix-Palencia Result,” plenary talk, SIAM PNW Conference, Corvallis, OR, Oct. 27-29, 2017.
- “Optimal Blaschke Products,” plenary talk, Householder Symposium XX on Numerical Linear Algebra, Blacksburg, VA, June 18-23, 2017.
- “Crouzeix’s Conjecture, Palencia’s Result, and a New Proof of an Old Result,” AMS Pacific Northwest Section meeting, Pullman, WA, Apr. 22-23, 2017.
- “Near Normal Dilations of Nonnormal Matrices and Linear Operators,” New Directions in Numerical Computation, Oxford, UK, Aug. 25-28, 2015.
- “The Lanczos Algorithm in Finite Precision Arithmetic, Revisited,” Householder XIX, Spa, Belgium, June 8-13, 2014; Charles University Applied Math Seminar, Mar. 6, 2014; SVG 2014, Stanford, CA., Jan. 25, 2014.
- “Crouzeix’s Conjecture,” Courant Institute Numerical Analysis Seminar, Nov. 22, 2013; Charles University Applied Math Seminar, Mar. 20, 2014.
- “Aggregation Based Algebraic Multigrid Methods,” Charles University Applied Math Seminar, Apr. 4, 2014.
- “K-Spectral Sets and Applications,” invited plenary speaker, ILAS 2013, Providence, R.I., June 3-7, 2013.
- “K-Spectral Sets and the Convergence Rate of GMRES,” IMA Distinguished Lecturer, 3rd IMA Conference on Numerical Linear Algebra and Optimization, Birmingham, UK, Sept. 10-12, 2012.
- “2-Spectral Sets and Similarity Transformations with Condition Number at Most 2”, Workshop on Numerical Ranges and Numerical Radii, Kaohsiung, Taiwan, July 13-16, 2012.
- “Crouzeix’s Conjecture and Perturbed Jordan Blocks,” invited plenary speaker, 42nd Annual Iranian Mathematics Conference, Rafsanjan, Iran, Sept. 5-8, 2011.
- “Bounds on Norms of Functions of Matrices Using the Field of Values,” PNWNAS, Pullman, WA, Oct., 2010.
- “GMRES Residual Norm Bounds Using the Minimal Norm Interpolating Function,” WCLAM, BIRS, May, 2010.

## BOOKS:

- Greenbaum, A. and T. Chartier, *Numerical Methods: Design, Analysis, and Computer Implementation of Algorithms*, Princeton, 2012.
- Greenbaum, A., *Iterative Methods for Solving Linear Systems*, SIAM, Philadelphia, 1997.
- Anderson, E., Z. Bai, C. Bischof, J. Demmel, J. Dongarra, J. DuCroz, A. Greenbaum, S. Hammarling, A. McKenney, S. Ostrouchov, and D. Sorensen. *LAPACK Users' Guide*, SIAM, Philadelphia, 1992.
- Hogben, L., R. Brualdi, A. Greenbaum, and R. Mathias, eds. *Handbook of Linear Algebra*, Chapman and Hall / CRC, Boca Raton, 2007.
- Golub, G., A. Greenbaum, and M. Luskin, eds. *IMA Volumes in Mathematics and its Applications, Volume 60: Recent Advances in Iterative Methods*, Springer-Verlag, New York, 1994.

## REFEREED PUBLICATIONS:

1. T. Caldwell, A. Greenbaum, and K. Li, *Some Extensions of the Crouzeix-Palencia Result*, <https://arxiv.org/abs/1707.08603>, submitted to SIAM Jour. Matrix Anal. Appl., 2017.
2. A. Greenbaum, F. Kyanfar, and A. Salemi, *On the Convergence Rate of DGMRES*, submitted to Lin. Alg. Appl., 2017.
3. A. Greenbaum and M. Overton. *Numerical Investigation of Crouzeix's Conjecture*, accepted in Lin. Alg. Appl., 2017.
4. A. Greenbaum, T. Caldwell, and K. Li. *Near Normal Dilations of Non-normal Matrices and Linear Operators*, SIAM Jour. Matrix Anal. Appl. 37 (2016), pp. 1365-1381.
5. A. Greenbaum, A. Lewis, and M. Overton. *Variational Analysis of the Crouzeix Ratio*, Math Programming (2016). doi:10.1007/s10107-016-1083-6, Nov., 2016.
6. D. Choi and A. Greenbaum. *An Algorithm for Finding a 2-Similarity Transformation from a Numerical Contraction to a Contraction*, SIAM Jour. Matrix Anal. Appl. 36 (2015), pp. 1248-1262.
7. D. Choi and A. Greenbaum. *Roots of Matrices in the Study of GMRES Convergence and Crouzeix's Conjecture*, SIAM Jour. Matrix Anal. Appl. 36 (2015), pp. 289-301.

8. A. Chen and A. Greenbaum. *Analysis of an Aggregation-Based Two-Grid Method for a Rotated Anisotropic Diffusion Problem*, Num. Lin. Alg. Appl. 22 (2015), pp. 681–701.
9. A. Greenbaum and D. Choi. *Crouzeix’s Conjecture and Perturbed Jordan Blocks*, Lin. Alg. Appl. 436 (2012), pp. 2342–2352.
10. B. Chang, A. Greenbaum, and E. Machorro. *Global Error Bounds for the Petrov-Galerkin Discretization of the Neutron Transport Equation*, Num. Lin. Alg. Appl. 18 (2011), pp. 141–154.
11. A. Greenbaum. *Upper and Lower Bounds on Norms of Functions of Matrices*, Lin. Alg. Appl. 430 (2009), pp. 52–65.
12. Mayo, A. and A. Greenbaum. *Fourth Order Accurate Evaluation of Integrals in Potential Theory on Exterior Regions*, Jour. Comput. Phys. 220 (2007), pp. 900–914.
13. A. Greenbaum. *Iterative Solution Methods for Linear Systems*, ch. 41 in *Handbook of Linear Algebra*, Chapman and Hall /CRC, Boca Raton, 2007.
14. Burke, J. and A. Greenbaum. *Characterizations of the Polynomial Numerical Hull of Degree  $k$* , Lin. Alg. Appl. 419 (2006), pp. 37–47.
15. Greenbaum, A. *Some Theoretical Results Derived from Polynomial Numerical Hulls of Jordan Blocks*, Elec. Trans. Num. Anal. 18 (2004), pp. 81–90.
16. Greenbaum, A. *Card Shuffling and the Polynomial Numerical Hull of Degree  $k$* , SIAM Jour. Sci. Comput. 25 (2004), pp. 408–416.
17. Faber, V., A. Greenbaum, and D. Marshall. *The Polynomial Numerical Hulls of Jordan Blocks and Related Matrices*, Lin. Alg. Appl. 374 (2003), pp. 231–246.
18. Greenbaum, A. *Generalizations of the Field of Values Useful in the Study of Polynomial Functions of a Matrix*, Lin. Alg. Appl. 347 (2002), pp. 233–249.
19. Greenbaum, A., V. Druskin, and L. Knizhnerman. *On Solving Indefinite Symmetric Linear Systems by Means of the Lanczos Method*, Jour. Comput. Math. and Math. Phys. 39 (1999), pp. 350–356.
20. Greenbaum, A. and A. Mayo. *Rapid Parallel Evaluation of Integrals in Potential Theory on General Three-Dimensional Regions*, Jour. Comp. Phys., 145 (1998), pp. 731–742.

21. Druskin, V., A. Greenbaum, and L. Knizhnerman. *Using Nonorthogonal Lanczos Vectors in the Computation of Matrix Functions*, SIAM Jour. Sci. Comput., 19 (1998), pp. 38–54.
22. Greenbaum, A., M. Rozložník, and Z. Strakoš. *Numerical Behavior of the Modified Gram-Schmidt GMRES Implementation*. BIT 37:3 (1997), pp. 706–719.
23. Greenbaum, A. *Estimating the Attainable Accuracy of Recursively Computed Residual Methods*, SIAM J. Matrix Anal. Appl., 18 (1997), pp. 535–551.
24. Greenbaum, A., V. Ptak, and Z. Strakoš. *Any Nonincreasing Convergence Curve is Possible for GMRES*, SIAM J. Matrix Anal. Appl., 17 (1996), pp. 465–469.
25. Cullum, J. and A. Greenbaum. *Relations Between Galerkin and Norm-Minimizing Iterative Methods for Solving Linear Systems*, SIAM J. Matrix Anal. Appl., 17 (1996), pp. 223–247.
26. Greenbaum, A. *Krylov Subspace Approximations to the Solution of a Linear System*, in Linear and Nonlinear Conjugate Gradient Methods, L. Adams and J. Nazareth, eds., SIAM, 1996.
27. Drkošová, J., A. Greenbaum, M. Rozložník, and Z. Strakoš. *Numerical Stability of GMRES*, BIT, 35 (1995), pp. 309–331.
28. Gurvits, L. and A. Greenbaum. *A Further Note on Max-min Properties of Matrix Factor Norms*, SIAM J. Sci. Comput., 16 (1995), pp. 496–499.
29. Greenbaum, A. and L. Gurvits. *Max-Min Properties of Matrix Factor Norms*, SIAM J. Sci. Comput., 15 (1994), pp. 348–358.
30. Greenbaum, A. and L. N. Trefethen. *GMRES/CR and Arnoldi/Lanczos as Matrix Approximation Problems*, SIAM J. Sci. Comput., 15 (1994), pp. 359–368.
31. Greenbaum, A. *The Lanczos and Conjugate Gradient Algorithms in Finite Precision Arithmetic*, in Proceedings of the Cornelius Lanczos International Centenary Conference, J. Brown, M. Chu, D. Ellison, and R. Plemmons, eds., SIAM, 1994.
32. Greenbaum, A. and Z. Strakoš. *Matrices that Generate the Same Krylov Residual Spaces*, in IMA Volumes in Applied Mathematics, Vol. 60: Recent Advances in Iterative Methods, G. Golub, A. Greenbaum, and M. Luskin, eds., 1994.

33. Greenbaum, A., L. Greengard, and G. McFadden. *Laplace's Equation and the Dirichlet-Neumann Map in Multiply-Connected Domains*, Jour. Comp. Phys., 105 (1993), pp. 267–278.
34. Greenbaum, A., L. Greengard, and A. Mayo. *On the Numerical Solution of the Biharmonic Equation in the Plane*, Physica D, 60 (1992), pp. 216–225.
35. Mayo, A. and A. Greenbaum. *Fast Parallel Iterative Solution of Poisson's and the Biharmonic Equations on Irregular Domains*, SIAM J. Sci. Stat. Comput., 13 (1992), pp. 101–118.
36. Greenbaum, A. and Z. Strakoš. *Behavior of Finite Precision Lanczos and Conjugate Gradient Computations*, SIAM J. Matrix Anal. Appl., 13 (1992), pp. 121–137.
37. Greenbaum, A. *Diagonal Scalings of the Laplacian as Preconditioners for Other Elliptic Differential Operators*, SIAM J. Matrix Anal. Appl., 13 (1992), pp. 826–846, 1992.
38. Greenbaum, A. *Behavior of Slightly Perturbed Lanczos and Conjugate Gradient Recurrences*, Lin. Alg. Appl., 113 (1989), pp. 7–63.
39. Greenbaum, A. and G. H. Rodrigue. *Optimal Preconditioners of a Given Sparsity Pattern*, BIT, 29 (1989), pp. 610–634.
40. Greenbaum, A., C. Li, and H. Zheng Chao. *Parallelizing Preconditioned Conjugate Gradient Algorithms*, Computer Phys. Comm., 53 (1989), pp. 295–309.
41. Greenbaum, A., C. Li, and H. Zheng Chao. *Comparison of Linear System Solvers Applied to Diffusion-Type Finite Element Equations*, Num. Math., 56 (1989), pp. 529–546.
42. Greenbaum, A. *Synchronization Costs on Multiprocessors*, Parallel Computing 10 (1989), pp. 3–14.
43. Engquist, B., A. Greenbaum, and W. Murphy. *Global Boundary Conditions and Fast Helmholtz Solvers*, IEEE Trans. on Magnetics, 25 (1989), pp. 2804–2806.
44. Klein, R., J. Castor, A. Greenbaum, D. Taylor, and P. Dykema. *A New Scheme for Multi-Dimensional Line Transfer. I. Formulation and 1-D Results*, Journal of Quantitative Spectroscopy and Radiative Transfer, 41 (1989), pp. 199–219.
45. Greenbaum, A. *A Multigrid Method for Multiprocessors*, Appl. Math. and Comp. (1986), pp. 75–88.

46. Greenbaum, A. and J. Ferguson. *A Petrov-Galerkin Finite Element Method for Solving the Neutron Transport Equation*, Jour. Comp. Phys., April, 1986.
47. Greenbaum, A. *Analysis of a Multigrid Method as an Iterative Technique for Solving Linear Systems*, SIAM J. Num. An., pp. 473–485, June, 1984.
48. Greenbaum, A. *Convergence Properties of the Conjugate Gradient Algorithm in Exact and Finite Precision Arithmetic*, Ph.D. Dissertation, University of California, Berkeley, June, 1981.
49. Greenbaum, A. *Comparison of Splittings Used with the Conjugate Gradient Algorithm*, Num. Math., 33 (1979), pp. 181–194.
50. Dubois, P. F., A. Greenbaum, and G. H. Rodrigue. *Approximating the Inverse of a Matrix for Use in Iterative Algorithms on Vector Processors*, Computing, (1979), pp. 257–268.
51. Greenbaum, A., A. J. Glass, and J. B. Trenholme. *Lens and Mirror Design Via the Principal Surface*, Applied Optics, pp. 2579–2582, October, 1976.