Fall 2019

Curriculum Vitae: William W. Symes

Education

AB, University of California, Berkeley, August 1971 (Mathematics)

Ph.D., Harvard University, June 1975 (Mathematics)

Professional Experience

[7/17-] Noah G. Harding Professor Emeritus, Computational and Applied Mathematics, Rice University
[7/17-12/19] Research Professor, Computational and Applied Mathematics, Rice University
[7/08-6/17] Professor, Earth Science, Rice University
[1/02-6/05] and [7/92-6/95]: Chair, Computational and Applied Mathematics, Rice University
[6/99-6/17] Noah G. Harding Professor, Computational and Applied Mathematics, Rice University
[6/98-6/17] Co-director, Center for Computational Geophysics, Rice University
[9/98-7/99] Visiting Professor, Stanford University
[1/92-] Director, The Rice Inversion Project
[5/89, 5/94] Visiting Professor, University of Paris IX
[7/83-6/99] Professor, Computational and Applied Mathematics, Rice University
[8/82-6/85] Visiting Professor and Associate Professor, Theoretical and Applied Mechanics, Cornell University (part time)
[9/79-6/85] Associate and Assistant Professor, Mathematics, Michigan State University
[9/77-8/79] Visiting Assistant Professor, Mathematics Research Center, University of Wisconsin
[9/74-8/77] Visiting Lecturer, Mathematics, University of British Columbia

Editorial Boards

Computational Geoscience, Associate Editor, 2015-2018

Inverse Problems, Editor-in-Chief, January 2005 - December 2009; International Advisory Board, 1990-95 and 2010-present.

Multiscale Modeling and Simulation, 2002-2006.

Modélisation Mathématique et Analyse Numérique, 1998-2005

Computational Geoscience, 1995-2006

SIAM Journal on Applied Mathematics, 1988-94

Professional Societies

Society for Industrial and Applied Mathematics (Fellow)
Society of Exploration Geophysicists
American Geophysical Union
Institute of Physics (Fellow)

Selected Honors, Awards, and Activities

Distinguished Lecturer, Society of Exploration Geophysicists, January-June 2018
Desiderius Erasmus Award, European Association of Geoscientists and Engineers, 2015.
Society for Industrial and Applied Mathematics, Geoscience Career Award, 2011.
Fellow, Institute of Physics, 2011.
Fellow (inaugural class), Society for Industrial and Applied Mathematics, 2009.
Appointed Professor in the Department of Earth Science, Rice University, upon the recommendation of its faculty, 2008.
Ralph E. Kleinman Prize, Society for Industrial and Applied Mathematics, 2001.
Ordway Distinguished Visiting Professor, School of Mathematics, University of Minnesota, 1998.
Founder and Director, The Rice Inversion Project - industry-university research consortium on inverse problems in reflection seismology, 1992-2019.
Principal designer, programmer, and distributor of the Rice Vector Library, a C++ class hierarchy for coupling complex simulation and optimization. Home page link on `wwsorcas.com`

Invited Lectures, Workshop and Conference Organizing

Plenary Lecturer, Society for Industrial and Applied Mathematics Annual Meeting, Portland, July 2018

Invited speaker, Chevron Workshops on Full Waveform Inversion, San Ramon and Houston, October 2012, November 2013, November 2014, December 2015, December 2016, November 2017, November 2018

Technical Program Committee, Society of Exploration Geophysicists Annual International

Meeting, Houston, September 2017

Keynote Speaker, Inverse Problems: from Theory to Application, Newton Institute, Cambridge University, Cambridge, September 2017

Invited Speaker, Workshop on Velocity Model Building - Full Wave vs Kinematic Approaches, European Association of Geoscientists and Engineers, Vienna, June 2017

Plenary Speaker, Applied Inverse Problems, Hangzhou, May 2017

Organizing Committee, Program on Computational Issues in Oil Field Applications; main organizer, Workshop on Full Waveform Inversion and Velocity Estimation; and tutorial speaker on Velocity Analysis, Institute For Pure and Applied Mathematics, University of California - Los Angeles, Los Angeles, May 2017

Invited Speaker, Workshop on Full Waveform Inversion, Society of Exploration Geophysicists, Dallas, October 2016

Invited Speaker, I-Quest Workshop, Saudi Aramco, Houston, October 2016

Invited Speaker, Review Workshop on SEAM, Society of Exploration Geophysicists, Houston, September 2016

Invited Speaker, Workshop on Open Source Software for Geophysics, European Association of Geoscientists and Engineers, Vienna, June 2016

Invited Speaker, Geophysical Society of Houston, Houston, January 2016

Invited speaker, Workshop on Advances in Modeling and Inversion, American Geophysical Union, San Francisco, December 2015

Invited speaker, Chevron Workshops on Full Waveform Inversion, San Ramon and Houston, October 2012, November 2013, November 2014, December 2015, December 2016

Co-Organizer, triple workshop of geophysical inversion, Society for Industrial and Applied Mathematics, Stanford, July 2015

Invited speaker, Workshop on Full Waveform Inversion, European Association of Geoscientists and Engineers, Madrid, June 2015

Plenary speaker, Inverse Problems: from Theory to Application, Institute of Physics workshop in honor of the 30th anniversary of the journal *Inverse Problems*, Bristol, August 2014

Principal lecturer, Graduate Summer Workshop on Seismic Inversion, Mathematical Sciences Research Institute, Berkeley CA, August 2013

KAUST-IAMCS Workshop on Modeling and Simulation of Wave Propagation and Applications, Thuwal, Saudi Arabia, May 2013

Organizing committee, Workshop on Full Waveform Inversion, Society of Exploration Geophysicists, Muscat, Oman, April 2013

Invited speaker, Workshop on inverse problems in the geosciences, Schlumberger Research, Houston, November 2012

Organizing committee, Summer Research Workshop, Society of Exploration Geophysicists, Charleston SC, August 2012.

Organizing committee and plenary speaker, workshop "Kinematic and waveform inversion", European Association of Geoscientists and Engineers, Copenhagen, Denmark, June 2012

Plenary speaker, Workshop on High Performance Computing in Oil & Gas, Rice University, Houston TX, March 2012.

Invited speaker, Applied Mathematics Seminar, Cambridge University, Cambridge UK, November 2011

Invited speaker, Department of Mathematics, University College London, London UK, November 2011

invited speaker, Department of Mathematics, University of Limerick, Limerick, Ireland, October 2011

Invited speaker, Schlumberger Cambridge Research, Cambridge UK, October 2011

invited speaker, Oxford University, Center for Nonlinear Partial Differential Equations, October 2011

Invited speaker, Schlumberger Research Symposium, Houston, TX, September 2011

Invited speaker, Baylor Symposium on Multi-scale Methods, Waco, TX, September 2011

Organizing committee, Newton Institute programme on Inverse Problems, Cambridge University, UK, July-Dec. 2011

Co-organizer, Industrial focus area on seismic imaging, International Conference on Industrial and Applied Mathematics, Vancouver BC, July 2011

Invited speaker, Tensor Geophysical Services, Houston TX, May 2011

Invited speaker, Michigan Center for Industrial and Applied Mathematics, spring meeting, May 2011

Co-organizer, Minisymposium on Upscaling for Wave Propagation, SIAM Conference on mathematical and computational issues in the Geosciences, Long Beach CA, March 2011

Instructor, short course on Seismic Imaging, Pacific Institute for Mathematical Sciences graduate summer school, University of Washington, August 2009

Principal lecturer, graduate summer school on Inverse Problems, University of Delaware (sponsored by Institute for Mathematics and its Applications), June 2009.

Organizer and Instructor, summer school on High Performance Computing, Rice University, May 2009

Invited lecturer, short course on Migration Velocity Analysis and Waveform Inversion, annual review meeting of the Center for Wave Phenomena, Colorado School of Mines, May 2009

Invited speaker, applied mathematics seminar, University of Houston, April 2009

Invited speaker, computational mathematics seminar, Texas A&M University, April 2009

Invited speaker, Workshop on High Performance Computing in the Oil and Gas Industry, Rice University, March 2009

Invited speaker, Workshop on Mathematics of Oil Exploration, annual meeting of the Mexican Mathematical Society, co-sponsored by the Pacific Institute for Mathematical Sciences, Monterrey, Mexico, October 2007

Invited speaker, Workshop on Mathematics: Analysis, Modeling, Optimization, and Simulation, University of Texas at Austin, October 2007

Invited speaker, special session on "Recent Advances and the Road Ahead", Society of Exploration Geophysicists Annual International Meeting and Exposition, San Antonio, TX, September 2007

Plenary lecturer, session organizer, and session speaker, Applied Inverse Problems 2007, Vancouver, Canada, June 2007

Plenary lecturer, Workshop on Reproducible Research in Computational Geophysics, University of British Columbia, September 2006

Plenary lecturer and co-organizer, Pacific Institute for Mathematical Sciences Workshop on Geophysical Inversion, University of Calgary, August 2006.

Pacific Institute for Mathematical Sciences Disinguished Visiting Lecturer on Inverse Problems, University of British Columbia and University of Washington, August 2005.

Minisymposium Co-organizer, Applied Inverse Problems 2005, Cirencester England, Inverse problems in wave propagation, June 2005.

Keynote speaker, MathGeo04 conference in honor of Prof. Guy Chavent upon his retirement, INRIA-Roquencourt, France, December 2004.

Organizer, Workshop on Interoperability of Object-Oriented Libraries for Scientific Computation, Los Alamos Computer Science Institute Symposium, Santa Fe NM, October 2003.

Plenary speaker, workshop on Imaging and Wave Propagation, University of Utah, July 2003.

Plenary lecturer and co-organizer, Pacific Institute for Mathematical Sciences Workshop on Geophysical Imaging, University of Calgary, July 2003.

Lecturer, Tutorial on Simulation-Driven Optimization, Institute for Mathematics and its Applications, University of Minnesota, January 2003.

Co-organizer, Minisymposium on Object-Oriented Optimization Software, Institute for Mathematics and its Applications, University of Minnesota, January 2003.

Lecturer, GO++ workshop, INRIA, Versailles, France, December 2002

Lecturer, C. I. M. E. Summer School on Mathematics of Imaging, Martina Franca, Italy, September 2002.

Program Committee, Year on Mathematics in the Geosciences, Institute for Mathematics and its Applications, University of Minnesota, Minneapolis MN, 2001-2.

Coorganizer and plenary lecturer, Mathematical Geophysics Summer School, Stanford University, 1998-2002.

Coorganizer, SIAM Conference on Mathematical and Computational Issues in the Geosciences, 1999.

Coorganizer, International Conference on Computation of Multivalued Traveltimes, INRIA, Rocquencourt, 1996.

Coorganizer, Symposium on Mathematical Methods in Geophysical Imaging, Society of Photooptical Instrumentation Engineers, 1993, 1994, 1995, 1996, and 1998.

Program Committee and CoChair for Winter Quarter, Year on Waves and Scattering, IMA, Minneapolis, 1994-95.

Coorganizer, International Conference on Inverse Problems of Acoustic and Elastic Waves, Cornell University, 1984.

Professional Service

Review Committee, Department of Mathematics, Rice University, 2012.

Search Committee, Dean of Engineering, Rice University, 2010-11.

Member of Numerics subcommittee and supervisor of benchmark code subproject, SEG Advanced Modeling Project, Phase I, 2007-2010

Consultant, Total E&P USA, 2005-present, ExxonMobil Upstream Reserch Co. 2007-present, Chevron Technology Company 2010-present, Geophysical Development Corporation, 2005-6, Paradigm Geophysical, 2008; Amoco Production Co., Mobil Research, ARCO Oil and Gas, Exxon Production Research Co., 1981 - 1991.

Principal investigator and member of the management board, Rice VIGRE project, June 2003 – June 2006.

Member, SIAM Council, 2002-3.

Member, Board of Governors, Institute for Mathematics and its Applications, University of Minnesota, Minneapolis MN, 2001-4.

Technical Program Committee, Society of Exploration Geophysicists Annual International Meeting and Exposition, 1995, 1997, and 1998.

Ph.D. and Postdoctoral Students

Ph.D. Students

Rakesh, *A linearized inverse problem for the wave equation*, Cornell University, 1986 [Chair of committee: L. Payne]; currently Associate Professor of Mathematics, University of Delaware.

Juan C. Meza, *Conjugate residual methods for almost symmetric linear systems*, Rice University, 1986; currently Director, Division of Mathematical Sciences, National Science Foundation, Washington DC.

Julia A. Olkin, *Linear and nonlinear deconvolution methods*, Rice University, 1986; formerly SRI Inc., Palo Alto CA.

Cheryl B. Percell [Miflin], *The effect of caustics in acoustic inverse scattering experiments*, Rice University, 1989; currently BHP Billiton. Houston TX.

R. Michael Lewis, *On the relation between the velocity coefficient and boundary value for the solution of the one dimensional wave equation*, Rice University, 1989; currently Professor and Chair, Department of Computer Science, Old Dominion University, VA.

David C. Dobson, *Stability and regularity of an inverse elliptic boundary value problem*, Rice University, 1990; currently Professor of Mathematics, University of Utah, Salt Lake City, UT. Recipient of IMA Industrial Postdoctoral Fellowship (1991-93) and NSF Mathematical Sciences Postdoctoral Fellowship (1992-95), Felix Klein Prize (2001).

Gang Bao, *Microlocal regularity of an inverse problem for the multidimensional wave equation*, Rice University, 1991; currently Chair Professor and Dean of Mathematical Sciences, Zhejiang University, Hangzhou, China. Recipient of IMA Industrial Postdoctoral Fellowship (1992-94), Feng Keng Prize (2003).

Mark S. Gockenbach, *An abstract analysis of differential semblance optimization*, Rice University, 1994; currently Professor and Chair, Department of Mathematical Sciences, Michigan Technical University, Houghton MI.

Hua Song *On a transmission inverse problem*, Rice University, 1994; formerly Avanti Inc., Menlo Park CA.

Susan E. Minkoff, *Multiparameter inversion and energy source estimation for a reflection seismic experiment*, Rice University, 1995; currently Professor of Mathematical Sciences, University of Texas at Dallas. Recipient of NSF Mathematical Sciences Industrial Postdoctoral Fellowship (1995-97).

Joakim O. B. Blanch, *A study of viscous effects in seismic modeling, imaging, and inversion: methodology, computational Aspects, and sensitivity*, Rice University, 1996; currently BHP Billiton, Houston TX.

Maissa A. Abd El-Mageed, *3D first arrival traveltimes and amplitudes via Eikonal and Trans-*

port finite difference solvers, Rice University, 1996; currently instructor, Faculty of Mathematics, University of Alexandria, Alexandria, Egypt.

Clifford J. Nolan, *Global analysis of linearized inversion for the acoustic wave equation*, Rice University, 1997; currently Lecturer in Applied Mathematics, University of Limerick, Ireland. Recipient of NSF Mathematical Sciences Postdoctoral Research Fellowship (1997-2000).

Jianliang Qian, *Geometrical optics for anisotropic qp waves: theories and numerical methods*, Rice University, 2000; currently Associate Professor, Department of Mathematics, Michigan State University, E. Lansing, MI.

Peng Shen, *Automatic Wave Equation Migration Velocity Analysis using Differential Semblance*, Rice University, 2004; currently Chevron, Houston.

Anthony Padula, *Software design for simulation-driven optimization*, Rice University, 2005; currently MITRE Corp., Washington DC.

Eric Dussaud, *Velocity analysis in the presence of uncertainty*, Rice University, 2006; currently Total E&P, Lagos, Nigeria.

Marco Enriquez, *The effects of coupling adaptive time-stepping and adjoint-state methods in optimal control problems*, Rice University, Rice Univeristy, 2011; currently Mitre Corporation, Washington D. C.

Tommy Binford, *Application of harmonic coordinates to interface problems on recular grids*, Rice University, 2011; currently Weatherford International, Kingswood TX.

Rami Nammour, *Approximate multi-parameter inverse scattering using pseudodifferential scaling*, Rice University, 2011; currently Total E&P USA, Houston TX.

Dong Sun, *Waveform inversion via nonlinear differential semblance optimization*, Rice University, 2012; currently Schlumberger Research, Houston TX.

Xin Wang, *Upscaling via transfer of approximation for acoustic waves*, Rice University, 2012; currently BP, Houston, TX.

Yin Huang, *Born wavefield inversion in shot coordinate domain*, Rice University, 2016; currently Amazon, Seattle WA.

Jie Hou, *Accelerating seismic imaging and velocity model building with approximate extended Born inversion*, Rice University, 2016; currently Shell, Houston, TX.

Lei Fu, *Migration velocity analysis and waveform inversion with subsurface offset extension*, Rice University, 2016; currently Schlumberger, Houston, TX.

Muhong Zhou, *Stable staggered grid mesh refinements for general anisotropic elastic wave simulations*, Rice University, 2017; currently IT contractor, Houston, TX.

Mario Bencomo, *Representation and estimation of seismic sources via multipoles*, Rice University, 2017; currently postdoctoral instructor, Department of Computational and Applied Mathematics, Rice University, Houston, TX.

Igor Terentyev, Nonlinear waveform inversion with surface-oriented extended modeling, Rice

University, 2017; currently Houston, TX.

Postdoctoral Scholars

Michel Kern (1992-94); currently INRIA, Rocquencourt, France.

Roelof Versteeg (1993-95); currently Sky Research, Inc., Etna, NH.

Alain Sei (1994-96); currently TRW Inc., Redondo Beach CA.

Quang-Hui Tran (1994-95); currently Institut Francais du Pétrole, Rueil Malmaison, France.

Lucio Santos (1995-96); currently Associate Professor of Mathematics, UNICAMP, Campinas, Brazil.

Kidane Araya (1995-98); formerly Sensorwise Inc., Houston TX.

Seongjai Kim (1995-97); currently Professor of Mathematics, Mississippi State University, Mississippi State, MS.

Chaoming Zhang (1996-98); currently Western Geco, Houston TX.

Philippe Ecoublet (1996-98); currently Paradigm Geophysical, Paris, France.

Christiaan Stolk (2001-2002); currently Associate Professor, Universiteit van Amsterdam, The Netherlands.

Kirk D. Blazek (2006-8); currently Assistant Professor of Instruction in Mathematics, University of Texas, Austin TX.

Tetyana Vdovina (2007-9); currently ExxonMobil Upstream Research Co., Houston, TX.

Guanghui Huang (2014-7); currently postdoctoral researcher, Michigan State University, East Lansing, MI.

Raanan Dafni 2014-7); currently Paradigm Geophysical, Tel Aviv, Israel.

Publications

Articles in Refereed Journals

1. W. W. Symes, *An integral representation for eigenfunctions of linear ordinary differential operators*, J. Math. Anal. Appl., 70 (1979), pp. 101–110.

2. W. W. Symes, *Inverse boundary value problems and a theorem of Gel'fand and Levitan*, J. Math. Anal. Appl., 71 (1979), pp. 121–251.

3. W. W. Symes, *Relations among generalized Korteweg-de Vries equations*, J. Math Phys., 20 (1979), pp. 721–725.

4. W. W. Symes, *Hamiltonian group actions and integrable systems*, Physica D: Nonlinear Phenomena, 1 (1980), pp. 339–374.

5. W. W. Symes, *Numerical stability in an inverse scattering problem*, SIAM J. Num. Analysis, 17 (1980).

6. W. W. Symes, *Systems of Toda type, inverse spectral problems, and representation theory*, Invent. Math., 59 (1980), pp. 13–51.

7. W. W. Symes, *The inverse reflection problem for a smoothly stratified elastic medium*, SIAM J. Math. Analysis, 12 (1981), pp. 421–453.

8. W. W. Symes, *The QR algorithm and scattering for the finite nonperiodic Toda lattice*, Physica D: Nonlinear Phenomena, 4 (1982), pp. 275–280.

9. W. W. Symes, *Impedance profile inversion via the first transport equation*, J. Math. Anal. Appl., 94 (1983), pp. 435–453.

10. W. W. Symes, *Trace theorem for solutions of the wave equation and the remote determination of acoustic sources*, Math. Methods in Appl. Sciences, 5 (1983), pp. 131–152.

11. F. Santosa and W. W. Symes, *Determination of layered acoustic media via multiple impedance profile inversions from plane wave data*, Geophys. J. Roy. Astr. Soc., 81 (1983), pp. 175–195.

12. P. Sacks and W. W. Symes, *Uniqueness and continuous dependence for a multidimensional hyperbolic inverse problem*, Comm. in P.D.E., 10 (1985), pp. 635–676.

13. S. H. Gray and W. W. Symes, *Stability considerations for one-dimensional inverse problems*, Geophys. J. Roy. Astr. Soc., 80 (1985), pp. 149–163.

14. W. W. Symes, *Linearization stability for an inverse problem in several-dimensional wave propagation*, SIAM J. Math. Analysis, 17 (1986), pp. 132–151.

15. W. W. Symes, *On the relation between coefficient and boundary values for solutions of webster's horn equation*, SIAM J. Math. Anal., 17 (1986), pp. 1400–1420.

16. P. Sacks and W. W. Symes, *Recovery of the elastic parameters of a layered half-space*, Geophys. J. Roy. Astr. Soc., 88 (1987), pp. 593–620.

17. F. Santosa and W. W. Symes, *Linear inversion of bandlimited reflection seismograms*, SIAM J. Sci. and Stat. Comp., 3 (1987), pp. 1307–1330.

18. F. Santosa, W. W. Symes, and G. Raggio, *Inversion of band-limited reflection seismograms using stacking velocities as constraints*, Inverse Problems, 3 (1987), pp. 477–499.

19. W. W. Symes and F. Santosa, *Computation of the Newton Hessian for least-squares solution of inverse problems in reflection seismology*, Inverse Problems, 4 (1988), pp. 211–233.

20. K. Bube, P. Lailly, P. Sacks, F. Santosa, and W. W. Symes, *Simultaneous determination of source wavelet and velocity profile using impulsive point-source data from a layered fluid*, Geophys. J., 95 (1988), pp. 449–462.

21. Rakesh and W. W. Symes, *On the relation between wavefront sets of the scatterer and the data*, Inverse Problems, 4 (1988), p. L23.

22. Rakesh and W. W. Symes, *Uniqueness for an inverse problem for the wave equation*, Comm. in P.D.E., 13 (1988), pp. 87–96.

23. F. Santosa and W. W. Symes, *High frequency perturbational analysis for the point-source response of a layered acoustic medium*, J. Comp. Phys., 74 (1988), pp. 318–381.

24. F. Santosa and W. W. Symes, *Reconstruction of blocky: impedance profiles from band-limited, poorly calibrated, normal incidence reflection seismograms*, Wave Motion, 10 (1988), pp. 209–230.

25. F. Santosa and W. W. Symes, *High-frequency perturbational analysis of the surface point-source response of a layered fluid*, Journal of Computational Physics, 74 (1988), pp. 318–381.

26. P. Sacks and W. W. Symes, *Velocity inversion from common offset data*, Inverse Problems, 5 (1989), pp. 407–423.

27. F. Santosa and W. W. Symes, *A model for a composite with anisotropic dissipation by homogenization*, Internat. J. Solids and Structures, 25 (1989), pp. 381–392.

28. P. Sacks and W. W. Symes, *The inverse problem for a fluid over a layered elastic half-space*, Inverse Problems, 6 (1990), pp. 1031–1054.

29. W. W. Symes, *Velocity inversion: A case study in infinite-dimensional optimization*, Math. Prog., 48 (1990), pp. 71–102.

30. W. W. Symes, *A differential semblance algorithm for the inverse problem of reflection seismology*, Computers and Math. with Appl., 22 (1991), pp. 147–178.

31. W. W. Symes, *Layered velocity inversion: a model problem from reflection seismology*, SIAM J. Math. Anal., 22 (1991), pp. 680–716.

32. W. W. Symes and J. Carazzone, *Velocity inversion by differential semblance optimization*, Geophysics, 56 (1991), pp. 654–663.

33. J. van Trier and W. W. Symes, *Upwind finite-difference calculation of travel-times*, Geophysics, 56 (1991), pp. 812–821.

34. G. Bao and W. W. Symes, *A trace theorem for solutions of linear partial differential equations*, Math. Meth. in the Appl. Sci., 14 (1991), pp. 553–562.

35. M. Lewis and W. W. Symes, *On the relation between the velocity coefficient and boundary value for solutions of the one-dimensional wave equation*, Inverse Problems, 7 (1991), pp. 597–632.

36. F. Santosa and W. W. Symes, *A dispersive effective medium for wave propagation in periodic composites*, SIAM J. Appl. Math., 51 (1991), pp. 984–1005.

37. W. W. Symes and J. Meza, *Conjugate residual methods for almost symmetric linear systems*, J. Optimization Theory and Applications, 72 (1992), pp. 415,440.

38. W. W. Symes, *A differential semblance criterion for inversion of multioffset seismic reflection data*, J. Geoph. Res., 98 (1993), pp. 2061–2073.

39. W. W. Symes, *The plane wave detection problem*, Inverse Problems, 10 (1994), pp. 1361–1391.

40. W. W. Symes and M. Kern, *Inversion of reflection seismograms by differential semblance analysis: Algorithm structure and synthetic examples*, Geophysical Prospecting, 99 (1994), pp. 565–614.

41. W. W. Symes, J. Robertsson, J. Blanch, and C. Burrus, *Galerkin-wavelet modeling of wave propagation: Optimal finite-difference stencil design*, Math. Comput. Modelling, 19 (1994), pp. 31–38.

42. A. Sei and W. W. Symes, *Error analysis of numerical schemes for the wave equation in heterogeneous media*, Applied Numerical Mathematics, 15 (1994), pp 465-480.

43. A. Sei and W. W. Symes, *Dispersion analysis of numerical wave propagation and its computational consequences*, Journal of Scientific Computing, 10 (1994), pp 1-27.

44. J. O. A. Robertsson, J. O. Blanch, and W. W. Symes, *Viscoelastic finite-difference modeling*, Geophysics, 59 (1994), pp. 1444–1456.

45. J. O. A. Robertsson, J. O. Blanch, W. W. Symes, and C. S. Burrus, *Galerkin-wavelet modeling of wave propagation: Optimal finite-difference stencil design*, Mathl. Comput. Modelling, 19 (1994), pp. 31–38.

46. W. W. Symes, J. Blanch, and J. Robertsson, *Modeling of a constant Q: Methodology and algorithm for an efficient and optimally inexpensive viscoelastic technique*, Geophysics, 60 (1995), pp. 176–184.

47. M. Gockenbach, W. W. Symes, and R. Tapia, *The dual regularization approach to seismic velocity inversion*, Inverse Problems, 11 (1995), pp. 501–531.

48. S. E. Minkoff and W. W. Symes, *Estimating the energy source and reflectivity by seismic inversion*, Inverse Problems, 11 (1995), pp. 383–395. Also in Proc. SPIE, 1994.

49. G. Bao and W. W. Symes, *Computation of pseudo-differential operators*, SIAM J. Sci. Comput., 17 (1996), pp. 416–429.

50. G. Bao and W. W. Symes, *On the sensitivity of solutions of hyperbolic equations to the coefficients*, Communications in PDE, 21 (1996), pp. 395–422.

51. M. S. Gockenbach and W. W. Symes, *The Hilbert Class Library: a library of abstract C++ classes for optimization and inversion*, Computers and Mathematics with Applications, 32 (1996).

52. W. W. Symes, L. Anne, and Q. Tran, *Dispersion and cost analysis of some finite difference schemes in one-parameter acoustic wave modeling*, Computational Geosciences, 1 (1997), pp. 1–33.

53. W. W. Symes and C. Nolan, *Anomalous reflections near a caustic*, Wave Motion, 25 (1997), pp. 1–14.

54. M. S. Gockenbach, A. J. Kearsley, and W. W. Symes, *An infeasible point method for minimizing the lennard-jones potential*, Computational Optimization and Applications, 8(3) (1997), pp. 273–286.

55. S. Kim and W. W. Symes, *Multifrequency simulation for acoustics*, Appl. Math. Letters, 10 (1997), pp. 47–52.

56. S. E. Minkoff and W. W. Symes, *Full waveform inversion of marine reflection data in the plane-wave domain*, Geophysics, 62 (1997), pp. 540–553.

57. C. Nolan and W. W. Symes, *Global solution of a linearized inverse problem for the wave equation*, Commun. in PDE, 22(5&6) (1997), pp. 919–952.

58. S. Kim and W. W. Symes, *Smooth detectors of linear phase*, Inverse Problems, 14 (1) (1998), pp. 101–112.

59. M. S. Gockenbach, M. J. Petro, and W. W. Symes, *C++ classes for linking optimization with complex simulations*, ACM Transactions on Mathematical Software, 25 (1999), pp. 191–212.

60. F. Santosa and W. W. Symes, *Multipole representation of small acoustic sources*, Chinese Journal of Mechanics, 16 (2000), pp. 15–21.

61. J. L Qian and W. W. Symes, *Paraxial eikonal solvers for anisotropic quasi-P traveltimes*, Journal of Comp. Phys., 173 (2001), pp. 1-23.

62. T. D. Dorney, J. L. Johnson, J. van Rudd, R. G. Baraniuk, W. W. Symes, and D. M. Mittleman, *Terahertz reflection imaging using Kirchhoff migration*, Optics Letters, 26 (2001), pp. 1513-1515.

63. J. L Qian and W. W. Symes, *Paraxial geometrical optics for quasi-P waves: theories and numerical methods*, Wave Motion, 35 (2002), pp. 205-221.

64. J. L Qian and W. W. Symes, *Adaptive finite difference method for traveltime and amplitude*, Geophysics, 67 (2002), pp. 167-176.

65. J. -L. Qian and W. W. Symes, *Finite difference quasi-P traveltimes for anisotropic media*, Geophysics, 67 (2002), pp. 147-155.

66. T. D. Dorney, W. W. Symes, R. G. Baraniuk, and D. M. Mittelman, *Terahertz multistatic reflection imaging*, J. Opt. Soc. Am., ser. A, 19 (2002), pp. 1432-1441.

67. M. S. Gockenbach, D. R. Reynolds, and W. W. Symes, *Efficent and automatic implementation of the adjoint state method*, ACM Transaction on Mathematical Software, 28 (2002), pp. 22-44.

68. J. -L. Qian and W. W. Symes, *A paraxial formulation for the viscosity solution of quasi-P eikonal equations*, Computers and Mathematics with Applications, 46 (2003), 1691-1701.

69. W. W. Symes and J. -L Qian, *A slowness matching Eulerian method for multivalued solutions of eikonal equations*, J. Sci. Comp., 19 (2003), pp. 501-526.

70. C. C. Stolk and W. W. Symes, *Smooth objective functionals for seismic velocity inversion*, Inverse Problems, 19 (2003), pp. 73-89.

71. T. D. Dorney, M. J. Rossow, W. W. Symes, and D. M. Mittelman, *Single-cycle terahertz electromagnetic pulses: A new test bed for physical seismic modeling*, Geophysics, 68 (2003), pp. 308-316.

72. A. Guitton and W. W. Symes, *Robust inversion of seismic data using the Huber norm*, Geophysics, 68 (2003), pp. 1310-1319.

73. C. C. Stolk and W. W. Symes, *Kinematic artifacts in prestack depth migration*, Geophysics, 69 (2004), pp. 562-575.

74. B. Biondi and W. W. Symes, *Angle domain common image gathers for migration velocity analysis by wavefield continuation imaging*, Geophysics, 69 (2004), pp. 1283-1298.

75. W. W. Symes, *Reverse time migration with optimal checkpointing*, Geophysics, 72 (2007), pp. SM213-222.

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