

**Wayne M. Lawton**

**Date and Place of Birth:** June 6, 1950, Manchester, Connecticut

**Nationality:** US Citizen, Singapore Permanent Resident

**Marital Status:** Married, No Children

**Address:** Block 29 Dairy Farm Road, 01-05, Singapore 679049

**Email:** matwml (at) nus.edu.sg

**Telephone:** Office (65) 65162749

**Education:**

Ph.D. Mathematics, Wesleyan University, 1972. Thesis: Expansive Transformation Groups.

B.A. Wesleyan University, 1972.

**Research Interests: Functional and Harmonic Analysis, Mathematical Physics, Systems Engineering**

My research accomplishments include proving the following conjectures:

- (1) (1971) proved the conjecture (communicated by Dean Montgomery and Ping Fun Lam) that no infinite dimensional topological group admits an expansive automorphism (paper 1, talk 1),
- (2) (1983) proved a conjecture of David Boyd concerning heights of algebraic numbers that is related to Derrick Henry Lehmer's Conjecture (paper 11, 13, talk 2, 3),
- (3) (1990) proved necessary and (1991) sufficient orthonormality conditions for wavelet bases (paper 24, 26),
- (4) (2008) proved the Hyperplane Zeros Conjecture of Jeffrey Lagarias and Yang Wang (paper 68).
- (5) (2009) derived spectral relationship between the kicked Harper operator and another operator (paper 69),
- (6) (2010) related syndetic sets to a special case of the Kadison-Singer problem (paper 72),

and developing the following methods:

- (1) (1978-1999) algorithms for holographic imaging, based on computing the phase of the Fourier transform of a compactly supported function of two variables from its modulus (paper 9, 10, 17, 19, 21), and for synthetic aperture radar imaging (paper 14, 15, 16, 18, 20, 29, 49, report 2, 3, 7, 8, patent 3),
- (2) (1990-2001) wavelet-based algorithms for image compression, numerical analysis, and learning (paper 22, 25, 30, 31, 33, 37, 41, 42, 46, 55, 57, 61, patent 4, 5),
- (3) (1995-2000) mathematical models for bioengineering (paper 34, 35, 37, 40, 43, 44, 48, 51, 53, 56),
- (4) (1995-2004) refinable functions and wavelet filter constructions (paper 28, 31, 32, 36, 38, 39, 45, 47, 50, 54, 58, 59, 61, 64, report 6, patent 2),
- (5) (1976-2005) applications of differential geometry and Lie groups (paper 3, 59, 60, 62, 63, 64, 65, 66).

I am currently trying to prove 1. that spectrums of the kicked Harper operators (paper 69, talks 86, 87, 89, 95) are Cantor sets whenever the rotation parameters are irrational, and 2. that the answer to the 1959 Kadison-Singer problem is no, based on a new relationship that I recently discovered between the Feichtinger conjecture (equivalent to the KS problem) and the theory of minimal shift dynamical systems (paper 72, talks 91, 92, 96-100).

## **Employment**

January 1999 - Present Associate Professor, Department of Mathematics, National University of Singapore.

June 1998 - December 1998 Associate Professor, Department of Computational Science and Senior Scientist, Center for Information Enhanced Medicine, National University of Singapore.

June 1997 - June 1998 Visiting Associate Professor, Department of Mathematics, National University of Singapore.

March 1993 - June 1997, Senior Scientist, Institute of Systems Science, National University of Singapore (now the Institute of Infocom Research).

April 1991 - March 1993, Consultant: The Analytic Sciences Corporation, Reading, Massachusetts, and Lockheed Research and Development Laboratories, Palo Alto, California, NASA.

September 1991 - August 1992, Adjunct Professor, Dept. Electrical Engineering, Northeastern Univ., Boston, MA.

June 1991 - July 1991, Visiting Scientist at Harvard/Smithsonian Center for Astrophysics, Cambridge, MA.

September 1988 - August 1990, Adjunct Professor, Dept. Electrical Engineering, Rice University, Houston, TX.

July 1987 - March 1991, Co-founder and Chief Scientist, AWARE, Inc., Cambridge, MA.

June 1985 - June 1987, Senior Project Engineer, TRW Defense Systems Group, Redondo Beach, CA.

September 1983 - December 1984, Lecturer at UCLA and at USC, Los Angeles, CA.

September 1981 - June 1985, Member of Technical Staff, Jet Propulsion Laboratory, Pasadena, CA.

April 1980 - September 1981, Research Engineer, Environmental Research Institute of Michigan, Ann Arbor, MI.

November 1978 - April 1980, Member of Technical Staff, MRJ, Inc., McLean, VA.

September 1976 - September 1978, Lecturer, Department of Mathematics, Chiang Mai University, Thailand.

September 1975 - September 1976, Assistant Professor, Department of Mathematics, University of Petroleum and Minerals, Dhahan, Saudi Arabia.

June 1975 - August 1975, Research Associate, Department of Mathematics, University of Houston, Houston, TX.

June 1974 - June 1975, Research Member, Institute for Advanced Study, School of Mathematics, Princeton, NJ.

June 1972 - August 1974, G. C. Evans Instructor, Department of Mathematics, Rice University, Houston, TX.

## **Undergraduate Courses Taught**

Approximation Theory, Calculus, Differential Equations, Elementary Numerical Analysis, Information and Communication, Linear Algebra, Matrix Computation, Non-Euclidean Geometry, Partial Differential Equations, Philosophy and Methodology of Science, Stochastic Processes, Theoretical Mechanics, Topology

## **Graduate Courses Taught**

Algebraic Topology, Computational Harmonic Analysis, Computational Mathematics, De Rham Cohomology and Hodge Decomposition, Filter Banks, Finite Elements, Functional Analysis, Wavelets, Fourier Analysis and Distributions

## **Special Programs**

Taught several courses in both the NUS Special Program in Science and the NUS University Scholars Program.

## Outreach and Service

Honorary Secretary NUS Staff Club (2010-2011), Mathematics Department Representative for the Science Research Program (SRP) (2001-2009) designed the 25 Mathematics Aptitude Test Questions each year. These questions were designed to select the most capable students into this program. I also supervised one Junior College SRP student for a project on random number generation. This student went on to complete a mathematics major with distinction at Harvard University. For several consecutive years I have also served as a designer and/or judge for other outreach programs including: CHAOS, Science Mentorship Program, and the Singapore Science and Engineering Fair. In 2009 and again in 2010 I supervised a team of three NUS students to compete in the Mathematical Contest in Modeling, supervised two NUS High School students to conduct a research project concerning the axiom of choice and its consequences. I previously served on the Research and Honors Committees, as Deputy Directors of the Center for Industrial Mathematics and the Center for Wavelets, Approximation, and Information Processing, as an Editor for the Journal of High Performance Computing, the Journal of Southeast Asian Mathematical Society, and am currently an editor for the Thai Journal of Mathematics. During my career at NUS I examined over 22 PhD, MSc and Honors Theses and refereed about 12 papers for international scientific journals each year.

## Graduate Students

LI Shuiying, PhD Conferred 10/2007, Thesis: "Parameter-uniform numerical methods for problems with layer phenomena: application in mathematical finance".

JIA Shuo, PhD Conferred 7/2006, Thesis: "Numerical gauge methods for variable density and multi-phase flows".

FAN Junjie, Bertrand, MSc Conferred 6/2008, Thesis: "Aspects of index theory".

LIOE Luis Tirtansanjaya, MSc Conferred 2004, Thesis: "Symmetry and its applications in mechanics".

JIA Shuo, MSc Conferred 2002, Thesis: "Numerical approximation methods for acoustic simulation".

FANG Jingrong, MSc Conferred 2000, Thesis: "Wavelet based method for sparse data interpolation".

YE Jieping, MSc Conferred 1999, Thesis: "Curve interpolation, approximation, and fairing".

## Honors Students

LIM Jing Zhan, Thesis: Mathematical modelling: an introduction to hidden Markov models, Submitted 4/2010.

LIU Liu, Thesis: Theory of discrete hidden Markov models and their applications, Submitted 4/2010.

FU Yixue, Thesis: Hidden Markov models, Submitted 4/2010.

ZHANG Yuzhu, Thesis: Hidden Markov models and their applications, Submitted 4/2010.

FOONG Joan Tack, Thesis: "The Ham Sandwich theorem and other adventures in topology", Submitted 11/2009.

XIONG Xi, Thesis: "Algebraic Numbers a la Yves Meyer", Submitted 3/2009.

ZHANG, Xinheng, Thesis: "Coordinates on  $R^n$  and their applications", Submitted 3/2008.

LIN Sijia, Thesis: "Wave propagation and Lyapunov localization in random media", Submitted 3/2007.

FAN Junjie, Bertrand, Thesis: " $SO(4)$  symmetry in Kepler orbits and hydrogen atoms", Submitted 3/2006.

CHOY Chee Chong, Thesis: "Topics in advanced calculus", Submitted 3/2004.

WAI Kok Hong, Thesis: "Methods for solving sparse positive definite systems", Submitted 3/1999.  
HO Shen Shyang, Thesis: "Exploring the mathematical aspects of quasicrystals", Submitted 3/1999.  
CHUA Bee Luan, Thesis: "Monte Carlo methods for time/frequency/scale analysis", Submitted 3/1998.  
WEE Jee Fung, Grace, Thesis: "Multiscale detection for discrete stationary random processes", Submitted 3/1998.

#### **Independent Study Module and UROPS Students**

THIANG Guo Chuan, Newly Designed ISM: "Foundational Issues of Quantum Physics", Submitted 10/2009.  
RAMMOHAN, Abhisek Vishwanath, Newly Designed ISM: "Altruism and game theory", Submitted 4/2009.  
CHIA Song Zhe, Andy, Newly Designed ISM: "Chaos and fractals", Submitted 4/2009.  
FONG, Brendan Chun-Leong, Ride-On ISM: "Galois theory of covering spaces", Submitted 4/2009.  
CHIA Chen Ming, UROPS Thesis: "Spectral theory and quantum chaos", Submitted 3/2009.  
PRAKASH, Ved, UROPS Thesis: "Iterative methods for computing eigenvalues for normal matrices", Submitted 10/2008.  
GOSAL, Darwin, UROPS Thesis: "Quantum Haar wavelet transforms and their applications", Submitted 6/2001.

#### **Students Co-Supervised**

CHING Chee Leong, MSc Thesis "Loop quantum gravity with matter coupling", Submitted 4/2009.  
LEEK Meng Lee, MSc Conferred 7/2008, Thesis: "Loop quantum gravity to loop quantum cosmology".  
WONG Jiang Fung, MSc Thesis Conferred 7/2008, Thesis "The methodology of loop quantum gravity".  
LU Shangyi, MSc Conferred 2007 Thesis "Pseudo-characteristic formulation and dynamic boundary conditions for computational aero-acoustics".  
LU Shangyi, Honors Thesis "Waves and homogenization" Submitted 2006.

#### **Honors, Memberships, Languages**

1998 Winner of the National Science Award, National Science and Technology Board, Republic of Singapore.  
1972 Rice Math Prize, Phi Beta Kappa, Sigma Xi.  
1968 Bausch and Lomb Science Award.  
Present or past member of: American Mathematical Society, New York Academy of Sciences, Southeast Asian Mathematical Society, Institute of Electrical and Electronics Engineers, American Physical Society, Optical Society of America, Society of Photo Instrumentation Engineers.  
Languages: Thai, German, and Mandarin Chinese

#### **Research Grants and Contracts**

During my career I was instrumental in obtaining approximately SG\$10 million in research grants.  
2009-2012 co-authored proposal and collaborator, SG\$127,866 grant from the Academic Research Fund to study spectral properties of driven Harper systems.  
2001-2005 principal investigator, SG\$45,000 grant from the Academic Research Fund, NUS, to study strain, vorticity, and turbulence.

2000-2004 collaborator, SG\$60,000 grant from the Academic Research Fund, NUS, to study functional analysis, harmonic analysis, and wavelets.

1998 principal investigator, SG\$79,000 grant from the Academic Research Fund, NUS, to study variational methods for biomedical computing.

1997 principal investigator, SG\$200,000 grant from the DSO, Singapore, to study signal detection.

1996 co-authored proposal and collaborator, SG\$3,200,000 grant from the NSTB and MOE, Singapore, to study wavelets.

1988 co-authored proposal and collaborator, US\$3,000,000 contract from the Defense Advanced Research Projects Agency, USA, to investigate wavelets at AWARE, Inc.

1985 principal investigator, US\$710,000 contract from the Central Intelligence Agency, USA, to develop algorithms to compute synthetic aperture radar images on hypercube multiprocessors at TRW.

## Publications

72. *Minimal sequences and the Kadison-Singer problem*, Bulletin of the Malaysian Mathematical Society, **33** (2), 169-176 (2010). <http://math.usm.my/bulletin/pdf/v33n2/v33n2p1.pdf>, arXiv:0911.5559

71. *Book Review: An Introduction to the Mathematical Structure of Quantum Mechanics, A Short Course for Mathematicians*, by F. Strocchi, International Journal of Quantum Information, **7** (3), 697–700 (2009).

70. (with S. Dhompongsa and W. Fupingwong) *Fixed point properties for  $C^*$ -algebras*, submitted January 2009. arXiv:0901.3646

69. (with A. Mouritzen, J. Wang, J. Gong) *Spectral relationships between kicked Harper and on-resonance double kicked rotor operators*, Journal of Mathematical Physics, **50**(3), Article 032103 (2009). ( 26 pages ), arXiv:0807.4276

68. *Proof of the hyperplane zeros conjecture of Lagarias and Wang*, The Journal of Fourier Analysis and Applications, **14**(4), 588–605 (2008). <http://arxiv.org/abs/math/0703249>

67. *Torus groups* Contributions in Mathematics and Applications II, East-West J. Mathematics, 1–15 (2007).

66. *Holonomy in biomechanics. A preliminary report* Contributions in Mathematics and Applications, East-West J. Mathematics, 1–12, (2005).

65. (with Y. Lenbury), *Interpolatory properties of trajectories in Lie groups*, p. 19-31 in Proceedings of Conference on Harmonic Analysis and its Applications in Osaka, Osaka, Japan, November 15–17, 2004.

64. *Hermite interpolation in loop groups and conjugate quadrature filter approximation*, Acta Applicandae Mathematicae, **84**(3),315–349 (2004).

63. *The inverse problem for Euler's equation on 2 and 3 dimensional Lie groups*, ScienceAsia, **28**(1),61–70 (2002).

62. *Geodesic approximations of 2D hydrodynamics*, p. 726–792 in Recent Advances in Computational Science and Engineering, Proceedings of the International Conference on Scientific and Engineering Computation (IC-SEC) 2002, edited by H. P. Lee and K. Kumar, Imperial College Press, London, 2002.

61. *Global analysis of wavelet analysis methods for Euler's equation*, Proceedings International Conference on Optimization of Finite Element Approximations and Splines and Wavelets, St. Petersburg, Russia, June 25–29, 2001.

60. (with L. Noakes), *Computing the inertia operator of a rigid body*, Journal of Mathematical Physics, **42**(4),1–11

(2001).

59. *Infinite convolution products and refinable distributions on Lie groups*, Transactions of the American Mathematical Society, **352**(6), 2913–2936 (2000).
58. (with C. Micchelli), *Bézout identities with inequality constraints*, Vietnam J. of Math., **28**(2), 1–29 (2000).
57. (with Y. Yu) *Learning from examples with spatial-adaptive wavelet-based reproducing kernels*, Proceedings of the IEEE Symposium of Circuits and Systems (ISCAS) in Geneva, Switzerland, May 28–31, 2000.
56. (with R. Raghavan and V. Viswanathan) *Tubes in tubes: Catheter navigation in blood vessels and its applications*, International Journal of Solids and Structures, **37**(22), 3031–3054 (2000).
55. *Conditional ellipticity and constrained optimization*, Advances in Computational Mathematics, 279–297 (Z. Chen, Y. Li, C. Micchelli and Y. Xu, ed.), Marcel Dekker, New York, 1999.
54. *Conjugate quadrature filters*, Advances in Wavelets, 103–119 (Ka-Sing Lau, ed.), Springer, Singapore, 1999.
53. (with M. Brady, K. Jung, R. Mulick, H. T. Nguyen, T. Poston, S. R. Rajan, V. Shalini, R. Viswanathan, Y. Yu, and G. Zhu) *Towards more physical virtual worlds: interactive haptic modeling of tensegrities and network structures*, Technical Sketches of SIGGRAPH’99, Los Angeles, 1999.
52. (with S. Meiyappan, R. Raghavan, R. Viswanathan and Y. Yu) *A civil engineering model of protein conformational change*, Journal of Molecular Modelling, **5**, 17–36 (1999).
51. (with S. Meiyappan, R. Raghavan, R. Viswanathan and Y. Yu) *Proteinmorphosis: a mechanical model for protein conformational change*, pages 341–351 in Proceedings of the Pacific Symposium on Biocomputing ’99, Hawaii, (edited by Russ Altman, A. Dunker, L. Hunter, T. Klein and K. Lauderdale), World Scientific, Singapore, 1999.
50. (with Z. Lin) *Matrix completion problems in multidimensional systems*, Proceedings of IEEE International Symposium on Circuits and Systems, Orlando, Florida, May 30 - June 2, 1999.
49. *Analytic signals and signal processing*, Proceedings of the SPIE Meeting, Orlando, Florida, April 5–9, 1999.
48. (with R. Raghavan, S. R. Ranjan and R. R. Viswanathan), *Ribbons and groups: A thin rod theory for catheters and filaments*, Journal of Physics A, **32**(9), 1709–1735 (1999).
47. (with S. L. Lee and Z. Shen), *Convergence of multidimensional cascade algorithm*, Numerische Mathematik, **78**, 427–438 (1998).
46. (with Y. Yu, Seng Luan Lee, Shaohua Tan, and Joos Vandewalle) *Wavelet based modelling of nonlinear systems*, pages 119–148 in Proceedings of the International Workshop on Advanced Black-Box Techniques for Nonlinear Modeling with Time-Series Prediction Competition, Catholic University of Leuven, Belgium, July 8–10, 1998.
45. (with C. A. Micchelli), *Construction of conjugate quadrature filters with specified zeros*, Numerical Algorithms, **14**, 383–399 (1997).
44. (with L. Ngee, T. Poston, R. Raghavan, S. R. Ranjan, R. Viswanathan, Y. P. Wang and Y. Yu), *Variational Methods in Biomedical Computing*, p. 447–456 in Computational Science for the 21st Century, (edited by M-O. Bristeau, G. Etgen, W. Fitzgibbon, J. L. Lions, J. Périaux and M. F. Wheeler), John Wiley, Sussex, England, 1997.
43. (with R. Raghavan, S. R. Ranjan and R. R. Viswanathan), *A continuum-mechanical model for cortical growth*, Journal of Theoretical Biology, **187**, 285–296 (1997).

42. *Information theory, wavelets, and image compression*, The International Journal of Imaging Systems and Technology, **8**, 1–9 (1997).
41. *A fast method to map functions forward*, Multidimensional Systems and Signal Processing, **8**, 1–9 (1997).
40. (with R. Raghavan, Yi Yu, and R. Viswanathan) *Robot tentacles: dynamics and control of flexible arms*, p. 480–484 in Proceedings of IEEE Singapore International Symposium on Control Theory and its Applications SISCTA 1997, published by IEEE Singapore Section, July 1997.
39. (with S. L. Lee and Z. Shen), *Stability and orthonormality of multivariate refinable functions*, SIAM Journal of Mathematical Analysis, **28**(4), 999–1014 (1997).
38. (with C. A. Micchelli), *Design of conjugate quadrature filters having specified zeros*, volume 3, p. 2069–2073, Proceedings of ICASSP97, held at Munich, Germany, April 21–24, 1997.
37. *Mathematical methods for active geometry*, Annals of Numerical Mathematics, **3**, 163–180 (1996).
36. (with S. L. Lee and Z. Shen), *An algorithm for matrix extension and wavelet construction*, Mathematics of Computation, **65**(214), 723–737 (1996).
35. (with T. Poston, L. Serra and B. C. Chua) *Interactive tube finding on a Virtual Workbench*, p. 119–123 in Wiley-Liss, Proceedings MRCAS 95, Medical Robotics and Computer Assisted Surgery, Baltimore, Maryland, November 5–7, 1995.
34. (with T. Poston and L. Serra), *Time-lag Reduction in a Medical Virtual Workbench*, p. 123–148 in “Virtual Reality and its Applications”, eds. R. Earnshaw, H. Jones, J. Vince, Academic Press 1995.
33. *Wavelet methods for medical image registration*, Proceedings of Second Asian Mathematics Conference, held at Suranaree University of Technology, Nakhon Ratchasima, Thailand, October 17–20, 1995.
32. (with S. L. Lee and Z. Shen), *Complete characterization of refinable splines*, Advances in Computational Mathematics, **3**, 137–145 (1995).
31. *Application of complex-valued wavelet transforms to subband decomposition*, IEEE Transactions on Signal Processing, **41**(12), 3566–3568 (1993).
30. (with R. Pinto), *Detection and discrimination using imaging spectroradiometric data*, Proceedings of the International Symposium on Spectral Sensing Research, Maui, November 1992.
29. *Multidimensional chirp algorithms for computing Fourier transforms*, IEEE Transactions on Image Processing, **1**(3), 429–431 (1992).
28. *Multilevel properties of the wavelet-Galerkin operator*, Journal of Mathematical Physics, **32**(6), 1440–1443 (1991).
27. (with R. A. Gopinath and C. S. Burrus), *Wavelet-Galerkin approximation of linear translational invariant operators*, Proceedings ICAASP, Toronto, Canada, May 13–17, 1991.
26. *Necessary and sufficient conditions for constructing orthonormal wavelet bases*. Journal of Mathematical Physics, **32**(1), 57–61 (1991).
25. (with R. Glowinski, M. Ravachol, and E. Tenenbaum), *Wavelet solution of linear and nonlinear elliptic, parabolic, and hyperbolic problems in one space dimension*, Proceedings of the Ninth International Conference on Computing Methods in Applied Sciences and Engineering, Paris, France, January 29–February 2, 1990, edited by

- R. Glowinski and A. Lichnewsky, SIAM, Philadelphia, 1990.
24. *Tight frames of compactly supported affine wavelets*, Journal of Mathematical Physics, **31**(8), 1898–1901 (1990).
  23. (with R. Raghavan), *Algebra of image transformations*, Proceedings of SPIE Symposium held in San Diego, California, July 1990.
  22. *Wavelet discretization methods*, Proceedings of the SPIE/SPSE Symposium on Electronic Imaging, Science, and Technology, held in Santa Clara, California, February 1990.
  21. *Linear and non-linear problems in Fourier imaging*, Proceedings of SPIE's Technical Symposia on Aerospace Remote Sensing, Held at Orlando, Florida, March 1989.
  20. *A new polar Fourier transform for computer-aided tomography and spotlight synthetic aperture radar*, IEEE Transactions on Acoustics, Speech, and Signal Processing, **36**(6), 931–933 (1988).
  19. *Spin glass models for the phase retrieval problem in two dimensions*, Proceedings of the Fourth Franco - SEAMS Joint Conference on Mathematical Methods, held at Chiang Mai University, Chiang Mai, Thailand, May 1988.
  18. *Multiprocessor synthetic image formation*, Proceedings of High Speed Computing Conference, Parallel Processing: Matching Execution Models with Problem Classes, sponsored by Lawrence Livermore and Los Alamos National Laboratories, held in Gleneden Beach, Oregon, March 1987.
  17. (with J. Morrison), *Factoring trigonometric polynomials regarded as entire functions of exponential type*, Journal of the Optical Society of America A, **4**, 105–111 (1987).
  16. *Applications of multiprocessing to Fourier aperture synthesis*, Proceedings of Annual Applied and Computational Mathematics Program Conference, held in Boston, October 1986.
  15. *A complete spectral characterization of quarter plane autoregressive models*, IEEE Transactions on Acoustics Speech and Signal Processing, **33**(6), 1617–1619 (1985).
  14. *Solution of the two dimensional spectral factorization problem*, Proceedings of the IEEE, **73**(2), 370–371 (1985).
  13. *A problem of Boyd concerning geometric means of polynomials*, Journal of Number Theory, **16**(3), 356–362 (1983).
  12. *Kronecker's theorem and rational approximation of algebraic numbers*, The Fibonacci Quarterly, **21**(2), 143–146 (1983).
  11. (with E. Dubrowolski and A. Schinzel), *On a problem of Lehmer*, pages 135–144 in Studies in Pure Mathematics, (volume in Honor of Paul Turan, published by the Hungarian Academy of Sciences), Birkhauser, Boston, Mass., 1983.
  10. *Mathematical results for the phase retrieval problem for bandlimited functions of several variables*, Proceedings of the Topical Meeting of the Optical Society of America on Signal Recovery and Synthesis with Incomplete Information and Partial Constraints, held at Incline Village, Nevada, January 12–14, 1983.
  9. *Uniqueness results for the phase retrieval problem for radial functions*, Journal of the Optical Society of America, **71**(1–2), 1519–1522 (1981).
  8. *A projective geometric proof of a theorem of Frobenius and Perron concerning positive matrices*, Journal of the Science Faculty of Chiang Mai University, **5**(1–2), 10–16 (1978).
  7. *Closed orbits for the central force problem*, Journal of the Science Faculty of Chiang Mai University, **5**(1–2), 1–9

(1978).

6. *A generalization of a theorem of Kronecker*, Journal of the Science Faculty of Chiang Mai University, **4**(1–2), 15–23 (1977).

5. *A relationship between sets of real numbers of first category and sets of real numbers of Lebesgue measure zero*, Journal of the Science Faculty of Chiang Mai University, **3**(2), 81–85 (1976).

4. *A trivial derivation of  $\sum_{n=1}^{\infty} \frac{1}{n^2} = \frac{\pi^2}{6}$* , Journal of the Science Faculty of Chiang Mai University, **3**(2), 76–80, (1976).

3. *Representations of the universal covering group of  $SL(2, R)$  and Hermite functions*, Arabian Journal for Science and Engineering, **2**(1), 33–38 (1976).

2. *Heights of algebraic numbers and Szego's theorem*, Proceedings of the American Mathematical Society, **46**(2), 47–50 (1975).

1. *The structure of compact connected groups which admit an expansive automorphism*, Springer-Verlag Lecture Notes in Mathematics, **318**, 182–196 (1973).

#### **Invited Talks and Conference Participation**

101. *Key results and applications of  $C^*$ -algebras; Rudiments of  $C^*$ -algebras*, Mathematics Seminar, University of Science Malaysia, Penang, Malaysia, 5; 8 July 2010.

100. *Feichtinger's conjecture for stationary sets*, presented at the workshop From Banach Spaces to Frame Theory and Applications, Norbert Weiner Center, University of Maryland, May 20-23, 2010.

99. *Feichtinger's conjecture for stationary Bessel sets*, Mathematics Seminar, Suranaree University of Technology, Nakorn Ratchasima, Thailand, February 16, 2010.

98. *A new strategy for Feichtinger's conjecture for stationary frames*, Applied and Computational Mathematics Seminar, Department of Mathematics, NUS, January 20, 2010.

97. *Riesz pairs and Feichtinger's conjecture*, Seminar Talk, Department of Mathematics, Chulalongkorn University, Bangkok, Thailand, December 25, 2009.

96. *Riesz pairs and Feichtinger's conjecture*, (Invited Talk), International Conference in Mathematics and Applications, Twin Towers Hotel, Bangkok, Thailand, December 17-19, 2009.

95. *Quantum Hall effect and quantum chaos*, Seminar Talk, Department of Physics, Chulalongkorn University, Bangkok, Thailand, July 24, 2009.

94. *Fixed point properties of  $C^*$ -algebras*, The 9th International Conference on Fixed Point Theory and its Applications, July 16-22, 2009, Department of Mathematics, National Changhua University of Education, Changhua, Taiwan.

93. *Short course on operator algebras*, Department of Mathematics, Chiang Mai University, July 9-14, 2009.

92. *Extending pure states on  $C^*$ -algebras and Feichtinger's conjecture*, (Invited Talk), 5th Asian Mathematical Conference, Putra World Trade Centre, Kuala Lumpur, Malaysia, June 22 - 26, 2009.

91. *Frames and the Kadison-Singer problem*, (Plenary Talk), Conference on Wavelets and Applications, Euler International Mathematical Institute, St. Petersburg, Russia, June 14-20, 2009.

90. *Ecological models*, Special Program in Science Talk, NUS, February 16, 2009.
89. *A quantum of chaos*, Mathematics Seminar, Mahidol University, Bangkok, Thailand, 26 December 2008.
88. *Equations of life*, Mathematics Seminar, Mahidol University, Bangkok, Thailand, 23 December 2008.
87. *Lie group approximation and quantum control*, (Keynote Talk), special session Lie Groups: Robotics, Vision and Control at the 7th Australia-New Zealand Mathematics Convention in Christchurch, New Zealand, Monday 8 - Friday 12 December 2008.
86. *Spectral relationships between kicked Harper and on-resonance double kicked rotor operators*, Mathematical Horizons for Quantum Physics, Session 1: Quantum Control and Dynamics, Institute of Mathematical Sciences, National University of Singapore, Singapore, 29 August 2008.
85. *Convergence of infinite convolution products to hyperfunctions on Lie groups*, 2nd Conference on Fixed Point Theory and Applications 2008, Rambhai Barni University, Chantaburi, Thailand, 25 July 2008.
84. *Polyphase geometry*, Chinese-French-Singaporean Joint Workshop on Wavelet Theory and Applications Institute of Mathematical Sciences, National University of Singapore, 11 June 2008.
83. *Participant*, Conference in Honor of CN Yang's 85th Birthday, Singapore, 31 October - 3 November 2007.
82. *Torus groups*, International Conference in Mathematics and Applications, Century Park Hotel, Bangkok, Thailand, August 15-17, 2007.
81. *Positively expansive maps and resolution of singularities*, Topology and Geometry Seminar, National University of Singapore, March 28, 2007.
80. *Positively expansive maps and resolution of singularities*, Colloquium talk, Mahidol University, Bangkok, Thailand, March 23, 2007.
79. *Data fitting: interpolation and approximation*, Colloquium talk, Mahidol University, Bangkok, Thailand, March 20, 2007.
78. *Applications of Lie theory*, Invited Speaker, Australian Mathematical Society Annual Meeting, Sydney, Australia, September 25-29, 2006.
77. *Waves and wavelets*, Invited Speaker, Workshop on Wavelets and Information Processing, Department of Mathematics, National University of Singapore, August 7, 2006.
76. *Holonomy in biomechanics*, Invited Speaker, International Conference in Mathematics and Applications, Bangkok, Thailand, December 25-27, 2005,
75. *Mechanical connections*, Keynote Speaker, Special Session on Applications of Differential Geometry in Engineering, Australian Mathematical Society Annual Meeting, Perth, Australia, September 26-30, 2005.
74. *Participant*, European Physical Society 13 Conference Beyond Einstein - Physics for the 21st Century, Bern, Switzerland, 11-15 July 2005.
73. *The physics of tsunamis*, Invited Speaker, The Raffles Institute, Singapore, April 8, 2005.
72. *Approximation of functions with constraints by trigonometric polynomials with applications to wavelet design*, Invited Plenary Speaker, International Symposium on Harmonic Analysis and its Applications at Osaka, Osaka, Japan, November 15-17, 2004.

71. *Invited Participant*, Conference on Recent advances in operator related function theory, dedicated to the celebration of 70-th birthday and 45 years in mathematics of Professor Joseph A. Cima, at Trinity College, Dublin, Ireland, August 4-6, 2004.
70. *Constrained approximation*, Speaker, Department of Mathematics, Indian Institute of Science; *Discretization methods for PDE's*, Speaker, Tata Institute, Indian Institute of Science; *Wavelets in Image Compression*, Speaker, GE John F. Welch Technology Center, all three talks were in Bangalore, India, June 2004.
69. *Constrained approximation*, Invited speaker, Second International Conference on Computational Harmonic Analysis, Vanderbilt University, Nashville, Tennessee, USA, May 24-30, 2004.
68. *Hermite interpolation in loop groups and conjugate quadrature filter approximation*, Invited speaker, Progress in Mathematics Conference, Mahidol University, Bangkok, Thailand, May 21-22, 2004.
67. *Approximation subject to nonlinear constraints*, Invited Speaker, Conference on Geometric Properties from Incomplete Data, Schloss Dagstuhl, Wadern, Germany, March 21-26, 2004.
66. *Hermite interpolation in loop groups and conjugate quadrature filter approximation*, Speaker, Department of Pure Mathematics, University of East Anglia, Norwich, UK, (visited Professors Graham Everest and Thomas Ward), December 19, 2003.
65. *Spatially adaptive kernel-based interpolation*, Speaker, Department of Computer Science, University College London, UK, (visited Dr Massimiliano Pontil), December 17, 2003.
64. *Loop groups, conjugate quadrature filters, and wavelet construction*, Invited Speaker, COM2MAC Conference on Computational Mathematics, Geongju, Republic of Korea, (sponsored by Pohang University), December 9-12, 2003.
63. *Loop groups, conjugate quadrature filters, and wavelet construction*, and *Kinematics of a rolling ball*, Korean Advanced Institute for Science and Technology (KAIST), both talks were held at KAIST, Daejeon, Republic of Korea, (visited Professor Oh Hong Kim), December 1-5, 2003.
62. *Contour integrals and their applications*, Speaker, The 11th International Conference on Finite or Infinite Dimensional Complex Analysis and Applications, Chiangmai, Thailand, July 27-31, 2003
61. *Convex optimization and data reconstruction*, Department of Applied Mathematics, University of Zaragosa, Spain, (visited Professor Mariano Gasca), May 2003.
60. *Fluid backflow modeling for drug infusion into brain tissue*, and *Elastic modeling of brain tissue for drug infusion*, Department of Mathematics, Mahidol University, Bangkok, Thailand, (visited Professor Yongwimon Lenbury), January 9-10, 2003.
59. *Theoretical and numerical analysis of scaling phenomena in two-dimensional euler flows*, Invited Speaker, The Second International Symposium on Computing Science, Zhongshan University, Guangzhou, China, December 20-23, 2002. (also gave similar talks at East China Normal and Fudan Universities in Shanghai prior to the symposium)
58. *Geodesic approximations of 2D hydrodynamics*, Invited Speaker, International Conference on Scientific and Engineering Computation (IC-SEC 2002), Raffles City Convention Center, Singapore, December 3-5, 2002.
57. *Geodesic approximations for two-dimensional eulerian fluid dynamics*, Invited Speaker, The 2002 International Conference on Harmonic Analysis and Applications, Zhejiang University, Hangzhou, China August 14-18, 2002.

56. *Modelling and computational simulation of eulerian flow*, Invited Speaker, International Conference on Computational Mathematics and Modelling, Bangkok, Thailand, May 22-24, 2002.
55. *The inverse equation for Euler's equation on Lie groups*, Invited Speaker, Singapore International Symposium on Topology and Geometry, National University of Singapore, Singapore, July 2-6, 2001.
54. *Global analysis of wavelet methods for Euler's equation*, Invited Speaker, International Conference on Optimization of finite-element approximation, splines and wavelets, St.-Petersburg, Russia, June 25-29, 2001.
53. Taught a two day short course on *Wavelets and multiscale analysis*, Institute of Technology Bandung, Bandung, Indonesia, February 20-21, 2001.
- Symmetry in art and biology*, NUS SPS Lecture, January 9, 2001.
52. *Characterization of real analytic varieties invariant under dilation endomorphisms*, Invited Speaker, Progress in Mathematics Conference, Mahidol University, Bangkok, Thailand, December 12 - 13, 2000.
51. *Geometric methods in classical mechanics*, Colloquium Talk, Department of Mathematics and Statistics, University of Western Australia, Perth, Australia, December 1, 2000.
50. *Mathematical parametrization methods*, Seminar Talk, Centre for Intelligent Information Processing Systems, Department of Electrical and Electronic Engineering, University of Western Australia, Perth, Australia, November 28, 2000.
49. *Characterization of real analytic varieties invariant under dilation endomorphisms*, Seminar Talk, Department of Mathematics and Statistics, University of Western Australia, Perth, Australia, November 22, 2000.
48. *Zero sets of eigenfunctions of transition operators*, Third Asian Mathematics Conference, University of the Philippines, Manila, October 23-27, 2000.
47. *Characterization of real analytic varieties invariant under dilation endomorphisms*, Department of Mathematics, State University of New York at Albany, Albany, New York, September 7, 2000.
46. Taught a five day short course on wavelets and gave five invited talks: *Transition operators and wavelet construction*, *Infinite convolution products and Taylor expansion*, *Positional notation - geometric and dynamic properties*, *Wavelet bases and multilevel algorithms*, and *Nonlinear analysis problems in industrial mathematics*, at four universities: Osaka, Osaka Kyoiku, Kyoto, and Ritsumeikan Universities in Japan, June 18 - July 8, 2000.
45. *Multiscale recursion and nonabelian harmonic analysis*, Conference on Wavelets and Fractals, National University of Singapore, May 24 - June 2, 2000.
44. Taught a two day workshop: *Wavelet analysis and its applications* and gave an invited talk: *Analysis across scales* at the International Workshop and Conference on Analysis and its Applications held at Chiang Mai University in Thailand, May 15-19, 2000.
43. *Statistical thermodynamics*, NUS SPS Lecture, February 21, 2000, and a series of talks in the NUS Mathematics Department in March/April 2000.
42. *The dynamics and geometry of multiresolution methods*, NUS Workshop on Computational Mathematics and Mechanics, February 14, 2000.
41. *Non-radial basis function methods for sparse data interpolation*, Colloquium Talk, Physics Department, University of Florida, (visited Professor John Klauder), December 15, 1999.

40. *Non-radial basis function methods for sparse data interpolation*, Colloquium Talk, School of Informatics and Engineering, Flinders University, Adelaide, Australia, (visited Professor William Moran), December 1, 1999.
39. *Non-radial basis function methods for sparse data interpolation*, Conference on Wavelet Analysis and its Applications, Zhongshan University, Guangzhou, China, November 15, 1999.
38. *Trajectories in Lie groups*, Colloquium Talk, Department of Mathematics and Statistics, University of Western Australia, Perth, Australia, (visited Professor Lyle Noakes), September 10, 1999.
37. *Interpolatory solutions of linear ODE's and extensions*, International Conference on Nonlinear Evolutional Equations and Infinite Dimensional Dynamical Systems and their Numerical Solutions, Yunnan University, Kunming, China, August 3, 1999.
36. *Interpolatory solutions of linear ODE's*, New faculty seminar, NUS, July 1999.
35. *Wavelets: mathematical issues and survey of application areas*, Colloquium Talk, Faculty of Science, Mahidol University, Bangkok, Thailand, (visited Professor Yongwimon Lenbury), June 11, 1999.
34. *Matrix completion problems in multidimensional systems*, (paper given by my coauthor) IEEE International Symposium on Circuits and Systems, Orlando, Florida, May 30 - June 2, 1999.
33. *Analytic signals and signal processing*, Invited Speaker, Annual Meeting of the Society of Photo Instrumentation Engineers, Orlando, Florida, April 5-9, 1999.
32. *Matrix completions and homotopy*, Wavelet seminar, NUS, March 3, 1999.
31. *Homogenization and spectral graph theory*, Workshop on Wavelets and Biomedical Signal Processing, NUS, December 21-22, 1998.
30. *Homogenization and spectral graph theory*, International Congress of Chinese Mathematicians, Beijing, December 12-16, 1998.
29. *Energy functions on graphs, wavelets, and multilevel algorithms*, International Congress of Mathematicians, Berlin, August 18-27, 1998.
28. *Detection of chirped signals*, Alphatech Corporation, Massachusetts, December 1997.
27. *Wavelet methods for constrained optimization*, Plenary Speaker, International Conference on Computational Mathematics, Bangkok, Thailand, December 8-10, 1997.
26. *Bezout's identity with inequality constraints*, Guangzhou International Symposium on Computational Mathematics, Zhongshan University, Guangzhou, China, August 11-15, 1997.
25. *Mathematical properties and computational applications of Daubechies' wavelet bases*, Department of Computer Science, National University of Singapore, May 1997.
24. *Rational wavelet design for molecular vibration analysis*, Workshop on Wavelets and their Applications, Chinese University of Hong Kong, Hong Kong, May 5-8, 1997.
23. *Rational wavelet design for molecular vibration analysis*, Inter-Faculty Industrial Seminar on Signal Processing, Image Compression, and Vibration Analysis Using Wavelets, National University of Singapore, May 1997.
22. *Design of conjugate quadrature filters having specified zeros*, Alphatech Corporation, Burlington, Massachusetts and AT&T Bell Laboratories, Murray Hill, New Jersey and ICAASP, Munich, Germany, April 21-24, 1997.

21. *Rational wavelet design and Wavelet methods for interpolating sparse data*, Department of Electrical Engineering, Delft University, Netherlands, (visited Professor DePerreta), April 21-24, 1997.
20. *Wavelets and applications to biomedical computing (gave 3 one hour lectures)*, Workshop on Algebraic Analysis, Suranaree University of Technology, Nakhon Ratchasima, Thailand, January 19-25, 1997.
19. *Refinable distributions on Lie groups*, Conference on Wavelets, Relations with Operators and Applications, University of North Carolina, Charlotte, July 24-28, 1996.
18. *Wavelets, prediction theory, and random processes*, AT&T Bell Laboratories, Murray Hill, New Jersey.
17. *Geometry and physics of elastic deformations*, IBM T. J. Watson Research Center, New York.
16. *Wavelet methods for medical image registration*, Second Asian Mathematics Conference, Suranaree University of Technology, Nakhon Ratchasima, Thailand, October 17-20, 1995.
15. *Computational algorithms for surface generation*, National University of Malaysia, Kuala Lumpur, Malaysia.
14. *Mathematical methods for active geometry*, International Conference on Computer Aided Geometric Design, University of Science, Penang, Malaysia, July 4-8, 1994.
13. *Affine multidimensional discrete Fourier transform based on fractal tiles*, Massachusetts Institute of Technology.
12. *Detection and discrimination using imaging spectroradiometric data*, International Symposium on Spectral Sensing Research, Maui, Hawaii. 15-20 November 1992.
11. *Wavelet based filter design*, NSF/CBMS Regional Conference on Wavelets, held at University of Lowell, Massachusetts, June 11-15, 1990.
10. *Wavelet discretization methods*, University of California, Berkeley, California.
9. *Applications of wavelets to image coding*, Sixth IEEE ASSP Workshop on Multidimensional Signal Processing, Monterey, California, September 6-8, 1989.
8. *Wavelet solution of linear and nonlinear elliptic, parabolic, and hyperbolic problems in one space dimension*, Conference on Wavelets and their Applications, held at Luminy University, Marseille, France, May 28-June 2, 1989.
7. *Fractal tilings of the plane*, Okayama University of Science, Japan.
6. *Multiprocessor synthetic aperture radar image formation and enhancement*, Conference on Applied and Computational Mathematics, Washington D.C., October 5-8, 1987
5. *Mineral identification and data compression for imaging spectroscopy*, Fourth IEEE ASSP Workshop on Multidimensional Signal Processing, Leesburg, Virginia, October 28-30, 1985.
4. *Phase reconstruction using object constraints in x-ray crystallography*, Third IEEE ASSP Workshop on Multidimensional Signal Processing, Lake Tahoe, California, October 19-21, 1983.
3. *Geometric means of polynomials and number theory*, AMS Meeting, Toronto, Canada, August 23-27, 1982.
2. *Asymptotic properties of roots of polynomials and number theory*, Seventh National Iranian Mathematics Conference, Azarabadagan University, Tabriz, Iran, March 1976.
1. *No infinite dimensional group admits an expansive automorphism*, AMS, Pennsylvania State University, University Park, Pennsylvania, August 31-September 3, 1971.

### Selected Scientific Reports

8. *Radar Imaging and Ambiguity Kernels*, Defence Science Organization National Laboratories Technical Report, Singapore, April 1998.
7. *Chirp Detection*, Defence Science Organization National Laboratories Technical Report, Singapore, April 1998.
6. (with H. L. Resnikoff), *Multidimensional wavelet bases*, Aware, Inc., Bedford, Massachusetts, USA, Technical Report (40 pages), May 1993.
5. (with J. Solomon, M. Quirk, E. Olsen), *A signal detection strategy for the SETI all sky survey*, Telecommunication and Data Acquisition Report (A NASA-JPL Publication), Vol. 42-83, pages 191-208, July 1985.
4. (with M. Lee), *Random field models for use in scene segmentation*, Final Report, NASA Fundamental Research Program - Task 677-24-41-04-36, (103 pages), March 1985.
3. (with J. Ebling and L. Thompson), *Synthetic aperture radar specification, simulation, theory and implementation*, ERIM Report 151600-58-T (123 pages), April 1982.
2. *An efficient sampling technique for sums of bandpass functions*, Telecommunication and Data Acquisition Report, Jet Propulsion Laboratory, volume 42-68, pages 3-7, January 1982.
1. *Multidimensional stochastic approximation using locally contractive functions*, U. Houston Rep. 46, August 1975.

### Patents

6. (with H. L. Resnikoff, W. M. Lawton, D. Pollen, and R. A. Gopinath), *Novel spread spectrum CODEC apparatus and method*, U. S. Patent 5121191, Assigned to Aware, Inc., 9 June 1992.
5. (with J. Huffman, and W. Zettler), *Image compression method and apparatus*, U.S. Patent 5,014,134, Assigned to Aware, Inc., 7 May 1991.
4. (with staff of AWARE, Inc.), *Weak orthogonal image compression application*, assigned to AWARE, Inc., allowed December 1990.
3. *Method and apparatus for computation of discrete Fourier transforms using array parallel processor*, Assigned to ERIM, serial number 530,099, filed May 1990.
2. (with H. Resnikoff), *Fractal tiling for multiple mirror telescopes*, U.S. Patent 4,904,073, Assigned to AWARE, Inc., 27 February 1990.
1. *Modular digital signal processor*, U.S. Patent 4,974,187, Assigned to Aware, Inc., 2 August 1989.