Curriculum Vitae

WIJESURIYA P. DAYAWANSA

Date of Birth March 27, 1956

Citizenship USA

EDUCATION

B.Sc.	(Electrical Engineering) University of Peradeniya, SRI LANKA	5/74-9/78
M.Sc.	(Electrical Engineering) Clarkson University, Potsdam, NY	9/80-9/82
D.Sc.	(System Science and Mathematics) Washington University, St. Louis, MO	9/82-8/86

ACADEMIC APPOINTMENTS

Assistant Lecturer, University of Peradeniya, SRI LANKA	9/78–9/80
Assistant Professor of Mathematics, Texas Tech University	9/86–9/89
Assistant Professor of Electrical Engineering and Systems Research Center University of Maryland at College Park,	9/89–9/92
Associate Professor of Electrical Engineering and Institute for Systems Research University of Maryland at College Park,	9/92–8/96
Professor of Mathematics Texas Tech University	9/96–

HONOR, AWARDS AND PROFESSIONAL ACTIVITY

Professional Service, Memberships

Representative of the SIAM Activity Group on Control and Optimization to SIAM News (January 1990 -).

Secretary/Treasurer of the SIAM Activity Group on Control and Optimization (January 1990 -Dec 1992).

Member of the Program Committee of the 29th IEEE Conference on Decision and Control, Hawaii, December 1990.

Member of the Program Committee of the 32nd IEEE Conference on Decision and Control, San Antonio, December 1993.

Member of the Program Committee of the Nonlinear Control System Design Symposium, June 1995.

Co-Organizer of the 1998 Texas Systems Day Symposium, Texas Tech University, Nov 1998.

Corresponding Editor of the Journal of Mathematical Systems, Estimation and Control (October 1990 -1998).

Associate Editor of Journal of Control, Optimization and Calculus of Variations. (Sept 1995 – present)

Associate Editor of The IEEE Transactions on Automatic Control (Jan 1993 - Jan 1996).

Associate Editor of the SIAM Journal on Control and Optimization (Jan 1991- Jan 1993).

Institute of Electrical and Electronics Engineers

American Mathematical Society

Society of Industrial and Applied Mathematics

Honors and Awards

1998-1999 Graduate Professor of the Year in the Department of Mathematics - Awarded by Texas Tech University Chapter of the Society of Industrial and Applied Mathematics.

Outstanding Systems Engineering Faculty Award - 94-95 (for contributions to the research and educational programs of the Institute for Systems Research) - Awarded by the Institute for Systems Research, University of Maryland at College Park.

Outstanding Electrical Engineering Professor of the Semester Award - Spring 1995 (for undergraduate education) - Awarded by the College Park Chapter of the Institution of Electrical and Electronic Engineers.

George Corcoran Memorial Award - 1993 (for significant contributions to the Electrical Engineering Education) - Awarded by the Department of Electrical Engineering, University of Maryland at College Park.

Plaque from the College Park Association of Parents - 1993 (for contributions to undergraduate education)

RESEARCH AND CREATIVE ACTIVITY

Published Research

Papers in Books:

1.1 "Some Global Aspects of the Feedback Linearization Problem," W. M. Boothby and W. P. Dayawansa; in **Differential Geometry: The Interface Between Pure and Applied Mathematics,** M. Luksic, C. Martin, W. Shadwick eds., Contemporary Mathematics Vol. 68, American Mathematical Society, 1987, 51-64.

1.2 "On the Global Tracking Problem for Nonlinear Systems," G. Knowles , W.P. Dayawansa and C. F. Martin; in **New Trends in Systems Theory,** G. Conte, A. M. Perdon and B. Wyman eds., Progress in Systems and Control Theory, Vol. 7, Birkhauser, 1991, 225-229.

1.3 "Two Examples of Stabilizable Second Order Systems," W. P. Dayawansa and C. F. Martin; in **Computation and Control,** K. Bowers and J. Lund eds., Progress in Systems and Control Theory, Vol. 1, Birkhauser, 1989, 53-63.

1.4 "Asymptotic Stabilization of Low Dimensional Systems," W. P. Dayawansa and C. F. Martin; in **Nonlinear Synthesis,** C. I. Byrnes and A. Kurzhansky eds., Progress in Systems and Control Theory, Vol. 9, Birkhauser, 1991, 53-67.

1.5 "Feedback Control of Chaotic Systems," F. Romeiras, C. Grebogi, E. Ott and W. P. Dayawansa; in **Chaotic Dynamics: Theory and Practice,** T. Bountis ed., Plenum, 1992.

1.6 "Recent Advances in the Stabilization Problem for Low Dimensional Systems," W. P. Dayawansa; to appear in **Geometry of Nonlinear Feedback and Optimal Control,** W. Respondek, B. Jakubcyk eds., Marcel-Decker 1997.

Papers in Archival Journals:

2.1 "Generalized Power System Reliability Theory, Part II," A.K. David and W.P. Dayawansa, *The Transactions of the South African Institute of Electrical Engineers*, Vol. 72, 1981, 301-307.

2.2 "Feedback Control of Singular Systems – Proportional and Derivative Feedback of the State," R. Mukundan and W.P. Dayawansa, *Int. J. of Systems Science*, Vol. 14, 615-32, 1983.

2.3 "Global State and Feedback Equivalence of Nonlinear Systems," W.P. Dayawansa, W.M. Boothby and D.L. Elliott, *Syst. and Contr. Lett.*, Vol. 6, 1985, 229-34.

2.4 "A Hybrid Parametrization of the Space of Linear Single Input, Single Output Systems," B.J. Ghosh and W.P. Dayawansa, *Syst. and Contr. Lett.*, Vol. 8, 1987, 231-239.

2.5 "Global (f, g)-invariance of Nonlinear Systems," W.P. Dayawansa D. Cheng, T. J. Tarn and W.M. Boothby, *SIAM J. on Contr. and Optimization*, Vol. 26, 1988, 1119-1132.

2.6 "Differential Geometric Methods in Hybrid Parametrization Problems," B.K. Ghosh and W.P. Dayawansa, *SIAM J. on Contr. and Optimization*, Vol. 26, 1988, 1149-1174.

2.7 "Observing Linear Dynamics with Polynomial Output Functions," W.P. Dayawansa and C. F. Martin; *Syst. and Contr. Lett.*, Vol. 9, 1987, 141-148.

2.8 "Feedback Transformations on Tori," W. P. Dayawansa, D. L. Elliott and C. F. Martin, *Mathematical Systems Theory*, Vol. 22, 1989, 213-219.

2.9 "Disturbance Decoupling, (f, g) - invariant and Controllability Subspaces of a Class of Homogeneous Polynomial Systems," W. P. Dayawansa and C. F. Martin, *SIAM J. on Contr. and Optimization*, Vol. 27, 1989, 108-119.

2.10 "Asymptotic Stabilization of Two Dimensional Real-analytic Systems," W. P. Dayawansa and C. F. Martin, *Syst. and Contr. Lett.*, Vol. 12, 1989, 205-211.

2.11 "A State Space Isomorphism Theorem for Minimal Dynamical Systems," D. Cheng, W. P. Dayawansa and C. F. Martin, *Acta Mathematicae Applicatae Sinica*, Vol. 7, 1991, 34-37.

2.12 "Asymptotic Stabilization of a Class of Smooth Two Dimensional Systems," W. P. Dayawansa, C. F. Martin and G. Knowles, *SIAM J. on Contr. and Optimization*, Vol. 28, No. 6, 1990, 1321-1349.

2.13 "Observability of Systems on Lie Groups and Coset Spaces," D. Cheng, W. P. Dayawansa and C. F. Martin, *SIAM J. on Contr. and Optimization*, Vol 28, 1990, 570-581.

2.14 "A Remark on a Theorem of Andreini, Bacciotti and Stefani," W. P. Dayawansa and C. F. Martin, *Syst. and Contr. Lett.*, Vol. 13, 1989, 363-364.

2.15 "Polynomials with Nonnegative Coefficients," R. W. Barnard, W. Dayawansa, K. Pearce and D. Weinberg; *Proc. of the American Mathematical Society.*, Vol 113, 1991, 77-87.

2.16 "Stabilization of Globally Noninteractive Nonlinear Systems Via Dynamic State Feedback," S. Battilotti and W. P. Dayawansa; *Journal of Mathematical Systems, Estimation and Control*, 1994

2.17 "Necessary and Sufficient Conditions for Noninteracting Control with Stability for a Class of Nonlinear Systems," S. Battilotti and W. P. Dayawansa; *Systems and Control Letters*, Vol 17, 1991, 327-338.

2.18 "Global Controllability of Reduced Input Nonlinear Systems," D. Cheng, W. P. Dayawansa and C. F. Martin, *Problems of Control and Information Theory*, Vol. 19, 1990, 289-311.

2.19 "On the Existence of Global Tchebychev Nets," S. Samelson and W. P. Dayawansa;to appear in *Proceedings of the American Mathematical Society*; Vol 347, No 2, Feb 1995, 651-661.

2.20 "Controlling Chaotic Dynamical Systems," F. J. Romeiras, C. Grebogi, E. Ott and W. P. Dayawansa; *Physica: D.*, Vol 58, 1992, 165-192.

2.21 "Asymptotic Stabilization of a Generic Class of Three Dimensional Homogeneous Quadratic Systems", W. P. Dayawansa, C. F. Martin and S. Samelson, *Systems and Control Letters*; Vol 25, No 2, Jan 1995, 119-127.

2.22 "Counter-examples on Global Stabilization by Dynamic Feedback," F. Mazenc, L. Praly and W. P. Dayawansa, *Systems and Control Letters*. Vol 23, 1994, 119-125. .

2.23 "Observing Chaos," P. So, E. Ott, W. P. Dayawansa, *Physics Review Letters A*, Vol 176, July,1993, 421-427.

2.24 "A Necessary and Sufficient Condition for the Perspective Observability Problem," W. Dayawansa, B. Ghosh, C. Martin, and A.Wang, *Systems and Control Letters*, Vol 25, 1995, 159-166.

2.25 "Nonlinear Controller for an Inverted Pendulum Having Restricted Travel," Q. F. Wei, W. P. Dayawansa and W. S. Levine , *Automatica*; Vol 31, June 1995, 841-850

2.26 "Optimal Control of a Rigid Body with Two Oscillators," P. S. Krishnaprasad, R. Yang and W. P. Dayawansa *Fields Institute Communications*, Vol. 7, 1995, 233-260.

2.27 "Observing Chaos: Deducing and Tracking the State of a Chaotic System from Limited Observation" P. So, E. Ott, W. P. Dayawansa, *Physical Review E*, 1996.

2.28 "Nonsmooth Simultaneous Stabilization of Nonlinear Systems: An Interpolation Method," B. Ho-Mock-Qai and W. P. Dayawansa, *Systems and Control Letters*, Vol 34, 1998, 43-53.

2.29 "Simultaneous Stabilization of Nonlinear Systems," B. Ho-Mock Qai and W. P. Dayawansa, *SIAM J. Contr. Optimization*, Vol 37, No6, 1999, 1701-1725, .

2.30 "A Converse Lyapunov Theorem for a Class of Dynamical Systems Which Undergo Switching," W. P. Dayawansa and C. F. Martin, *IEEE Trans. Automat. Contr.*, Vol. 44, April 1999, 751-760.

2.31 "Theory of Reference Frames and Biological Control", N. Kirupaharan and W. P. Dayawansa, to appear in the "Mathematical and Computer Modeling"

2.32 "Linear Systems with Polynomial Inputs," R. Barnard, C. F. Martin and W. P. Dayawansa, to appear in *Mathematical and Computer Modeling*.

2.33 "Smooth Feedback, Global Stabilization and Disturbance Attenuation of Nonlinear Systems with Uncontrollable Linearization," C. Qian, W. Lin and W. P. Dayawansa, Submitted to *SIAM J. Contr. and Optimization*.

Papers in Refereed Conference Proceedings :

3.1 "Interconnected Power System Reliability Evaluation with Load Correlation and Transmission Constraints," A.K. David and W.P. Dayawansa, *Proc. of the Second IFAC Symposium on Automatic Control in Power Generation, Distribution and Protection*, Pretoria, South Africa, September 1980.

3.2 "Global Linearization by Feedback and State Transformation," W.P. Dayawansa, W.M. Boothby and D.L. Elliott, *Proc. of the 24th IEEE Conf. on Decision and Control*, IEEE, New York, December 1985, 1042-49.

3.3 "On the Global (f, g)-invariance of a Class of Nonlinear Systems," W.P. Dayawansa, D. Cheng, T. J. Tarn and W.M. Boothby, *Proc. of the 25th IEEE Conf. on Decision and Control*, IEEE, New York, December 1986, 2065-2069.

3.4 "Identification of Linear Systems via Prony's Method," G. Ammar, D. Cheng, W.P. Dayawansa and C. F. Martin, *Proc. of the 1989 Conf. on the Mathematical Theory of Networks and Systems,* M. A. Kaashoek, J. H. van Schuppen and A. C. M. Ran eds., Birkhauser, Boston, 1990, 483-489.

3.5 "Some Sufficient Conditions for Global Feedback Equivalence of a Nonlinear System to an Invariant System on a Torus," W.P. Dayawansa, C. F. Martin, and D. Elliott, *Proc. of the 1987 Conf. on the Mathematical Theory of Networks and Systems,* C. I. Byrnes, C. F. Martin and R. E. Saeks eds., North-Holland, New York, 1988, 399-403.

3.6 "Decoupling and Disturbance Decoupling of a Class of Homogeneous Polynomial Systems: A Subspace Approach," W. P. Dayawansa and C. F. Martin, *Proc. of the 26th IEEE Conf. on Decision and Control*, IEEE, New York, December 1987, 509-513.

3.7 "Observing Linear Dynamics with Polynomial Output Functions," W. P. Dayawansa and C. F. Martin, *Proc. of the 26th IEEE Conf. on Decision and Control*, IEEE, New York, December 1987, 977-979.

3.8 "On the Topology and Geometry Aspects of Universally Observable Systems," C. I. Byrnes, W. P. Dayawansa and C. F. Martin, *Proc. of the 26th IEEE Conf. on Decision and Control*, IEEE, New York, December 1987, 963-966.

3.9 "Global Heyman's Lemma for Nonlinear Systems," D. Cheng, W. P. Dayawansa and C. F. Martin, *Proc.of the 27th IEEE Conf. on Decision and Control*, IEEE, New York, December 1988, 58-63.

3.10 "Asymptotic Stabilization of Two Dimensional Polynomial Systems," D. Cheng, W. P. Dayawansa and C. F. Martin, *Proc. of the IFAC Symposium on Nonlinear Control Design,* Capri, Italy; Pergamon Press, New York, June, 1989, 185-188.

3.11 "Asymptotic Stability of Nonlinear Systems with Holomorphic Structure," W. P. Dayawansa and C. F. Martin, *Proc. of the 28th IEEE Conf. on Decision and Control*, IEEE, New York, December 1989, 2252-2254.

3.12 "Some Sufficient Conditions for the Asymptotic Stabilizability of Three Dimensional Homogeneous Systems," W. P. Dayawansa and C. F. Martin, *Proc. of the 28th IEEE Conf. on Decision and Control*, IEEE, New York, December 1989, 1366-1370.

3.13 "A Global Nonlinear Tracking Problem," W. P. Dayawansa, C. F. Martin and G. Knowles, *Proc. of the 29th IEEE Conf. on Decision and Control*, IEEE, New York, December 1990, 1168-1171.

3.14 "On the Existence of Homogeneous Feedback in the Disturbance Decoupling Problem for Homogeneous Polynomial Systems," W. P. Dayawansa, *Proc. of the 1st European Control Conference,* Hermes, Paris, 1991, 2054-2058.

3.15 "Necessary and Sufficient Conditions for Noninteracting Control with Stability for a Class of Nonlinear Systems," S. Battilotti and W. P. Dayawansa, *Proc. of the 1991 American Control Conference,* American Automatic Control Council, Evanston, IL, 1991, 1107-1112.

3.16 "Controlling Chaotic Dynamical Systems," F. J. Romeiras, E. Ott, C. Grebogi, and W. P. Dayawansa, *Proc. of the 1991 American Control Conference*, American Automatic Control Council, Evanston, IL , 1991, 1112 -1120.

3.17 "Mechanical Systems with Partial Damping," L. S. Wang, P. S. Krishnaprasad and W. P. Dayawansa , *Proc. of the 30th IEEE Conf. on Decision and Control*, Brighton, UK, 1991, 2356-2360.

3.18 "Stabilization of Globally Noninteractive Nonlinear Systems via Dynamic State Feedback," S. Battilotti and W. P. Dayawansa, *Proc. of the 30th IEEE Conf. on Decision and Control*, Brighton, UK, 1991, 52-57.

3.19 "Control Problems on Principal Bundles and Nonholonomic Mechanics," P. S. Krishnaprasad, R. Yang, and W. P. Dayawansa, *Proc. of the 30th IEEE Conf. on Decision and Control*, Brighton, UK, 1991, 1133-1138.

3.20 "Recent Advances in the Stabilization Problem for Low Dimensional Systems," W. P. Dayawansa, *Proc of the IFAC conference on Nonlinear Control Systems Synthesis* (*Plenary Lecture*), Bordeaux, France, June 1992.

3.21 "Asymptotic Stabilization of Three Dimensional Homogeneous Systems," W. P. Dayawansa, C. F. Martin and S. Samelson, *Proc. of the 31st IEEE Conf. on Decision and Control*, Tucson, Az, Dec 1992.

3.22 "Analysis of a Nonlinear Dynamic Inverse Control Strategy and Its Digital Implementation," J. Reilly, W. P. Dayawansa, W. S. Levine, C. Huang and G. Knowles, *Proc. of the 31st IEEE Conf. on Decision and Control*, Tucson, Az, Dec 1992.

3.23 "Wavelet Based Identification of a Flexible Structure with Surface Mounted Smart Actuators and Sensors," R. Rezaiifar, Y. C. Pati, P. S. Krishnaprasad and W. P. Dayawansa, *32nd IEEE Conf. on Decision and Control*, San Antonio, Tx,Dec 1993, 486-492.

3.24 "Modelling of Impact on a Flexible Beam," Q.F. Wei, P. S. Krishnaprasad and W. P. Dayawansa, *32nd IEEE Conf. on Decision and Control*, San Antonio, Tx, Dec 1993, 1377-1383.

3.25 "Wavelet Decompositions and Control of the ATB1000 Fixture," R. Rezaiifar, W. P. Dayawansa and P. S. Krishnaprasad; presented at the *American Control Conference*, San Fransisco, June 1993.

3.26 "A Fast Recursive Algorithm for System Identification and Model Reduction Using Rational Wavelets," Y. C. Pati and R. Rezaiifar, W. P. Dayawansa and P. S. Krishnaprasad, *Proceedings 27th Annual Asilomar Conference on Signals Systems and Computers*, Pacific Grove, CA, Nov 1993, 35–39.

3.27 "Chaplygin Dynamics and Lagrangian Reduction," R. Yang, P. S. Krishnaprasad and W. P. Dayawansa, *Proceedings of the 2nd International Conference on nonlinear Mechanics*, Beijing, China, August, 1993, 745-749.

3.28 "Approximation of Dynamical Effects Due to Impact on Flexible Bodies," Q. Wei, W. P. Dayawansa and P. S. Krishnaprasad; to appear in the *Proceedings of the American Control Conference*, Baltimore, June 1994.

3.29 "Optimal H_∞ Control For Impulsive Disturbances," Q. F. Wei, W. P. Dayawansa and P. S. Krishnaprasad; to appear in the *Proceedings of the 1994 Conference on Information Sciences and Systems,* Princeton, March 1994.

3.30 "Computer Modeling and Control System Design for a Mobile Robot," N. Subramanium and W. P. Dayawansa; *Proceedings of the IFAC NOLCOS Conference*, June 1995.

3.31 "Design and Control of a Walking Machine," S. Azarm, W. P. Dayawansa, N. Farvardin, A. Tits, L-W. Tsai; Proceedings of the *American Control Conference* , *Proceedings of the 1995 American Control Conference,* Seattle, June 1995, 1082-1086.

3.32 "H_∞ Control For Impulsive Disturbances: A State-Space Solution," Q. F. Wei, W. P. Dayawansa and P. S. Krishnaprasad; *Proceedings of the American Control Conference*,Seattle, June 1995, 4379-4383.

3.33 "Identification for Intelligent Control of 2D Smart Composites," T. Kugarajah, P. S. Krishnaprasad and W. P. Dayawansa; *Proceedings of the SPIE Conference on Mathematics and Control in Smart Structures,*, San Diego, March 1995, Paper number 26.

3.34 "Smart Motor Concept Based on Piezoelectric-Magnetosrictive Resonance," R. Venkataraman, J. Loncaric, W. P. Dayawansa, and P. S. Krishnaprasad, *Proceedings of the SPIE +Conference on Mathematics and Control in Smart Structures,*, San Diego, March 1995, Paper number 83.

3.35 "Observability of the Riccati Equation," W. P. Dayawansa, C. F. Martin,; *proceedings of the 34th IEEE Conference on Decision and Control,* New Orleans, December 1995, 317-321.

3.36 "Nonsmooth Robust Stabilization of a Family of Linear Systems in the Plane," B. Ho-Mock-Qai and W. P. Dayawansa; Proceedings of the *IEEE Conference on Decision and Control* , December 1996.

3.37 "Nonsmooth Simultaneous Stabilization of Nonlinear Systems: Interpolation of Feedback Laws," B. Ho-Mock-Qai and W. P. Dayawansa; Proceedings of the *IEEE Conference on Decision and Control* , December 1996.

3.38 "Stability of Switching Systems," W. P. Dayawansa and C. F. Martin; Proceedings of the *IEEE Conference on Decision and Control* , December 1996.

3.39 "Sufficient Conditions for the Simultaneous Stabilizability of Nonlinear Systems," B. H0-Mock-Qai and W. P. Dayawansa, Proceedings of the *American Control Conference,* 1997.

3.40 " Simultaneous Stabilization of Two Planar Nonlinear Systems Arising From Bifurcation Problems," C. F. Martin and W. P. Dayawansa; Proceedings of the *IEEE Conference on Decision and Control* , December 1997.

3.41 " Reference Frames in Learning and Control," N. Kirupaharan and W. P. Dayawansa, Proceedings of the *IFAC world congress,* Beijing, July 1999.

3.42 "Topological Obstructions to Simultaneous Stabilization," B. Ho-Mock-Qai and W. P. Dayawansa, Proceedings of the IEEE Conference on Decision and Control, Phoenix, December 1999.

3.43 "Van der Pol Oscillator Networks," Proceedings of the *IEEE Conference on Decision and Control* , N. Wang and W. P. Dayawansa, December 1999.

3.44 "On Global Lyapunov Functions of Nonlinear Autonomous Systems," A. Wang and W. P. Dayawansa, Proceedings of the *IEEE Conference on Decision and Control,* Phoenix, December 1999.

3.45 "Some Nonlinear Control Problems in Biology," W. P. Dayawansa, Proceedings of the *3rd Asian Control Conference,"* Shanghai, China, July 2000.

3.46 "Convergence of Extended Kalman Filtering to Locate a Moving Target in Wildlife Telemetry," M. S. Sugathadas, C. F. Martin and W. P. Dayawansa, to Appear in the Proceedings of the *IEEE Conference on Decision and Control,* Sydney, December 2000.

3.47 "Phase Locking in the Mammalian Circadian Clock," J. Miller, W. P. Dayawansa, P. Hallgren and C. F. Martin, to Appear in the Proceedings of the *IEEE Conference on Decision and Control,* Sydney, December 2000.

3.48 "Control of Pursuit Eye Movement," M. S. Sugathadasa, W. P. Dayawansa and C. F. Martin, to Appear in the Proceedings of the *IEEE Conference on Decision and Control,* Sydney, December 2000.

Other Papers :

4.1 "Stability of Randomly Switched Systems," W. P. Dayawansa and C. F. Martin; presented at the *Mathematical Theory of Networks and Systems Conference,* St. Louis, June 1996.

4.2 "Modelling and Control of Shape Change," A. Girard and W. P. Dayawansa; presented at the *Mathematical Theory of Networks and Systems Conference,* St. Louis, June 1996.

4.3 "Nonsmooth Robust Stabilization of a Family of Linear Systems in the Plane," B. Ho-Mock-Qai and W. P. Dayawansa; presented at the *Mathematical Theory of Networks and Systems Conference,* St. Louis, June 1996.

4.4 "On the Geometry of the Simultaneous Stabilization Problem," Presented at the AMS Summer Research Institute on Differential Geometry and Feedback Control, Boulder, Colorado, July 1997.

4.5 "Stability Across a Bifurcation Point," Presented at the Texas Systems Day, Rice University, Houston, October, 1997.

4.6 "Mathematical Modeling of the Mammalian Circadian Rhythm," Presented at the Summer Conference on Nonlinear Control, Tsinhua University, July 2000.

Invention Disclosures

5.1 "Hybrid Motor," University of Maryland Invention Disclosure, PS-96-048 (with J. Loncaric, P. S. Krishnaprasad and R. Venkataraman), 1996.

Funding

1. PI - National Science Foundation - ECS 8802483. "Geometric Methods in Feedback Control and Parameterization Problems." Aug 31, 1988 till January 31, 1992 to the Total Amount of $100,236

2. Researcher – US Army Research Office for the University Research Initiative Program. "Smart Structures Technology: Innovations and Applications to the Rotorcraft Systems." May 1, 1992 till April 30, 1997 to the Total Amount is $ 2,300,000

3. PI - National Science Foundation - ECS 9109344. "Design and Control of a Walking Robot." July 1, 1992 till June 31, 1996 to the Total Amount of $ 389,999.

4. Researcher – Office of Naval Research. "Control of Chaotic Motion is Cargo Transfer at Sea." January 15, 95 till January 15, 1996 to the Total Amount of $139,495.

5. Researcher – National Science Foundation. "Sensor Integration and Control of Semiconductor Manufacturing Processes." October 1, 1995 till September 31, 1998 to the total amount of $ 550,000.

6. PI – National Science Foundation - ECS 9707927. "A Class of Robust Stabilization Problems in Nonlinear Control." September 1, 1997 till September 31, 2001 to the Total Amount of $ 179,399.

7. Co-PI – National Science Foundation - ECS 9720357. "Learning and Intelligent Systems." September 1, 1997 till September 31, 2001 to the Total Amount of $ 720,000.

8. NATO Scientific and Environmental Affairs Division. "Simultaneous Stabilization of Nonlinear Systems." September 1, 1998 till September 1, 1999 to the Total Amount of BF 216,000 (approximately $6000).

9. PI – Texas Higher Education Coordinating Board ARP Grant. "Modeling the Human Muscular Control System." January 2000-January 2002 to the Total Amount of $70,203.

10. Co-PI – US Army SBCCOM. "Systems Approach to Modeling and Simulation of Dispersal of Chemical and Biological Agents." September 25, 2000 till xxxx to the Total Amount of $272,328.

Students Graduated

1. Chang Lin-Huang, M. Sc. in Mathematics, Texas Tech University, Lubbock, TX 79409. May 1989

2. Ramin Rezaiifar, M. Sc. in Electrical Engineering, University of Maryland, College Park, Md 20742. August 1993.

3. Narayanan Subramanium, M. Sc. in Electrical Engineering, University of Maryland, College Park, Md 20742. May 1994.

4. George Kantor, M. Sc. in Electrical Engineering, University of Maryland, College Park, Md 20742. August 1995.

5. T. Kugaraja, M. Sc. in Electrical Engineering, University of Maryland, College Park, Md 20742. August 1995.

6. Qifeng Wei, Ph. D. in Electrical Engineering,University of Maryland, College Park, Md 20742. May, 1995.

7. Scott James, Ph. D. in Applied Mathematics, University of Maryland, College Park, Md 20742. May 1996.

8. Bertina Ho-Mock-Qai, Ph. D. in Electrical Engineering, University of Maryland, College Park, MD 20742. September 1996.

9. Andy Girard, Ph. D. in Applied Mathematics, University of Maryland, College Park, MD 20742. Date: May 1997.

10. James Conn, M. Sc. in Mathematics, Texas Tech University, Lubbock, TX 79409. December 1998.

11. N. Kirupaharan, M. Sc. in Mathematics, Texas Tech University, Lubbock, TX 79409. August 1999.

12. N. Wang, M. Sc. in Mathematics, Texas Tech University, Lubbock, TX 79409. August 1999.

Statement on Research and Courses Taught

Research.

This is a self evaluation of my research experience since receiving my Ph. D. degree in September, 1986 and a brief sketch of my current interests.

Most of my research work has been on the development of new techniques for the analysis and design of nonlinear control systems and fall into one of the top four categories in the listing below. Work described in items (v) and (vi) are somewhat experimental in nature. During the past three years I have taken a keen interest in understanding the control theoretic aspects of the cortical-muscular coordination. My current research interests include nonlinear stabilization, cortical-muscular control, quantum computing algorithms, and modeling the spread of hazardous chemical and biological agents.

1. Feedback Linearization
2. Parametrization Problem for Spaces of Linear Systems
3. Disturbance Rejection and Noninteracting Control
4. Stabilization of Nonlinear Control Systems
5. Mobile Robots
6. Smart Structures and Materials
7. Control of Chaotic Dynamics
8. Signal generation and control in the cortical-muscular system.
9. Other Work
10. Current Research Interests.

The following contains a brief description of the work done in each of above categories in the following subsections. Numbers below within square brackets refer to the papers listed above the vita pages 2-9.

1. *Feedback Linearization*

   Feedback Linearization refers to the technique of utilizing feedback control and a change of state variables in order to transform a nonlinear control system to a linear one. This has become a cornerstone in nonlinear control theory since it allows the control designer to use a virtually inexhaustible array of techniques available in linear control theory.

Prior to my contributions to this area, the focus had mainly been on local aspects of the problem, i.e. the change of variables take place on some small neighborhood of an equilibrium point. The focus of my Ph. D. thesis was to understand the global aspects of this problem. The papers [1.1]*, [2.3] and [3.2] (joint work with my co-advisors D. L. Elliott and W. M. Boothby)contain a complete description of the global obstructions that have to be overcome in order to solve the problem. Some of these obstructions are in terms of nonexistence of finite escape times for certain differential equations and the others are on certain subtle aspects of the arrangement of a variety of surfaces with respect to each other, i.e. holonomy of a related foliation.

Some of the techniques developed have since been used by C. I. Byrnes and A. Isidori in their work on the global feedback stabilization problem, and by R. Marino in his work on the adaptive output feedback control problem.

2. *Parametrization Problem for Spaces of Linear Systems*

The problem of fitting a mathematical model for a control system or a process, of which the internal structure is not known to any degree of certainty, is called the *system identification problem*. For the sake of simplicity, one frequently attempts to fit a linear model. The standard procedure is to iterate one of many popular algorithms until a suitable match is found. The first step in utilizing such a scheme is a choice of a reasonable parameter space for linear systems. Such choices are also important when one has to satisfy a multitude of design constraints in choosing a feedback controller.

Work done by Brockett, Krishnaprasad and others have led to various parameterized spaces of linear control systems. The salient feature of these spaces is that they consist of systems of fixed dimension (the basic spaces are called rat(n), which stands for rational functions of McMillan degree n). These spaces have smooth structures (i.e. they are manifolds) so that it is possible to do calculus on them (this is a desirable feature since it allows the development of algorithms based on directional search schemes). The drawback is that *a priori* information regarding the dimensionality of the unknown dynamic system is required before being able to choose the parameter space. The work in [2.4] and [2.6] (joint work with Professor B. K. Ghosh) was among the first to propose a smoothly parameterized space of linear systems of variable, but bounded dimension. Furthermore, via an over parametrization, we were able to ensure that the space has a very simple geometric structure. This is generally regarded as a desirable property since it fosters the construction of globally convergent algorithms. Our work has lead to interesting further developments by other researchers, S. Morse being prominent among them.

3. *Disturbance Rejection and Noninteracting Control*

Dynamical systems are in general subject to unknown disturbances. For safe and reliable operation it is vital to ensure that these disturbances do not affect the performance in a sig-

*Refers to articles listed in the vita pages 2 through 9

nificant way. One of the standard ways of doing so is to first identify certain output variables which have to be controlled precisely and then demand that the feedback controller should be capable of isolating the effect of the disturbances on these output variables. The problem of designing such feedback controllers is called the disturbance rejection problem. Another problem, the noninteracting control problem is very closely related to the disturbance rejection problem. The objective here is to ensure that each of the output variables is controlled by exactly one input, and unaffected by the remaining inputs.

In my early work [2.5] and [3.3] (joint work with Professors D. Cheng, T. J. Tarn and W. M. Boothby) the focus was on the global aspects of these problems. There it was pointed out for the first time that the geometric notion of *parallel transport* is the key to uncovering the mysteries associated with this problem. This way of thinking about the problems has lead to new insight, new algorithms for solving the problems, and has pointed out that these problems have much in common with certain abstract problems that have a central role in modern differential geometry.

Both of the problems are important paradigms in the control theory of mechanical systems. Usually these systems possess extra features such as certain symmetries. For example the dynamics of a system of coupled rigid bodies in space are invariant under a change of reference frame of the observer. As a result, the dynamic models for such systems can be written down in such a way that certain structural features become transparent. We have been searching for means to incorporate these features into the solution of the disturbance rejection and noninteracting control problems. The papers [2.9],[2.13] and [3.6] (joint work with Professors D. Cheng and C. F. Martin) represent early attempts in this regard.

More recently we have investigated the possibility if using dynamic feedback to solve the noninteracting control problem while preserving stability of the overall system [2.17],[2.18],[3.15] and [3.18] (joint work with a visiting graduate student Stefano Battilotti). A comprehensive solution to the problem was given for the first time in [2.18]. We were able to generalize some of the results that Stefano Battilotti had previously obtained to a global setting in [2.17].

4. *Stabilization of Nonlinear Control Systems*

Most control systems operate near an equilibrium point during the normal operation. However, in some cases such as certain advanced experimental aircraft, these equilibrium points are unstable, and feedback control has to be employed to ensure stability. Even though it is well understood how to stabilize a linear system, we are only beginning to understand the complexities involved in stabilizing a nonlinear system. Thus, our viewpoint was to start with very low dimensional systems and gradually increase the level of complexity of the dynamic model.

Our starting point was the case of a two dimensional real analytic system of which the control term is effective at the origin. The work of M. Kawski showed that controllability i.e. the ability to drive the state from one point to another, is sufficient for the stabilizability of

such systems. In [2.10],[2.13] and [3.10] (joint work with C. F. Martin and G. Knowles) we showed that asymptotic controllability to the origin is a necessary and a sufficient condition for the stabilizability of such systems by using continuous feedback. This is indeed one of three necessary conditions that Brockett has already given for systems in arbitrary dimensions. In addition we defined certain indices associated to a system which dictate whether or not the system is stabilizable with smooth feedback control.

In [1.4] and [3.12] (joint work with C. F. Martin) we focussed on the case of a three dimensional nonlinear control system. Again, to reduce complexity, we assumed that there is a one parameter symmetry group which allows us to cut down the dimensionality by one. This now yields a problem in which the critical information is contained in the global structure of a real analytic variety on the sphere. In contrast, in the two dimensional stabilization problem quoted above, the critical information is contained in the local structure of a real analytic variety. This explains the difficulty associated with unraveling the mysteries of the three dimensional case. In[1.4] and [3.12] we gave some new necessary conditions and sufficient conditions in this case. State of the art on this problem (as of 1997) containing a summary of our work is contained in the review paper [1.6].

In [2.28-29] and [3.36,37,39,40] we studied the problem of simultaneously stabilizing a family of nonlinear control systems near a *bifurcation* point. Bifurcation points are defined as those at which no linear controller can simultaneously stabilize the family. We proposed new geometric constructions for stabilizing controllers. A closely related problem is that of stabilizing a family which undergoes random switching. This is an entirely different problem from simultaneous stabilization in the sense that stability must hold regardless of the switching pattern. Our work in [2.30] and [3.38] focused on finding conditions under which a family of linear systems will be stable regardless of the switching pattern. Lately this work has been attracting a lot of attention.

5. *Mobile Robots*

   University of Maryland Walking Machines project with undergraduate/graduate and educational/research components. This research was conducted in association with a cross-cutting undergraduate course titled walking machines. The tangible outcome was a walking machine. In this effort the undergraduates were also taught advanced mechanical design and control theory education and graduate students were given an opportunity to apply their research results to an advanced prototype. Papers [2.28-32] were the direct outcomes of this project. In addition, the University of Maryland walking machine was demonstrated at the National Science Foundation for a short period as an exhibit in a project aimed at attracting talented high school students to science and engineering.

6. *Smart Structures and Materials*

   Finding ways to use smart actuators, i.e, piezoceramic, electrostrictive, magnetostrictive actuators etc., has become a very attractive research area in the recent past. These types of actuators are capable of operating at very high frequencies, and deliver large actuation forces

and torques. However, the amplitude of actuation is severely limited. This demands novel control methods. In addition, these systems are quite complex in their physical characteristics, and hence not amenable to physics based modeling. Novel identification methods were devised in order to identify dynamic models for them. Papers [2.25], [3.23-26], and [3.33-34] are outcomes of this project. The smart motor concept described in [3.34] resulted in a University of Maryland invention disclosure [5.1].

7. *Control of Chaos*

   It has been demonstrated that strange attractors are ubiquitous in nonlinear dynamics. Traditional schools of nonlinear control have spent much time in understanding and developing control tools for shaping the behavior near an equilibrium point or a periodic orbit, while ignoring any strange attractors. Work by Ott, Grebogi and Yorke have initiated the study of control systems evolving in a chaotic attractor. In [1.5], [2.23,27] and [3.16] the idea of controlling chaos was generalized, and methods for estimating the state from partial observations were investigated.

8. *Signal generation and control in the cortical-muscular system*

   During the past two, years I have been interested in understanding control theoretic aspects of the cortical-muscular complex. Thus far our work has focused on three topics.

   (a) Theory of Reference Frames.

   Theory of reference frames is a very powerful concept in mathematical psychology with applications in cognition, linguistics, motor control, and learning among many other areas. In essence this says each physiological and psychological task is ordered hierarchically in the form of several principal fiber bundles, and a complex task can be simplified into a simpler task via a bundle reduction. In [2.31], [3.41] and parts of [3.45] we have examined this concept in connection with human locomotion, exhibited the explicit bundle structure, and demonstrated a connection between the control theoretic concept of backstepping and the bundle reductions in reference frame theory.

   (b) Occulomotor Control System.

   It is well known that pursuit eye movements entail feedback control and ought to be thought of as a moving target tracking problem. In [3.48] this problem was studied using tools from nonlinear control theory, and it was demonstrated that it is indeed possible to describe candidate control laws generated in the cortical-muscular plant governing the occulomotor system that can perform target tracking operation in a manner comparable to what has been reported by experimentalists.

   (c) Abstract Representation of Cortical Signals

   It is well known that neuronal signals take the shape of a train of spikes. Biologists have adapted the Hodgkin and Huxley model, which describes an electrical circuit analog of a neuron, in order to approximately represent these spike trains with arbitrary accuracy.

However, it is generally believed that the timing pattern of a spike train contains almost all the information needed to decode a neuronal signal. This being the case it is both interesting and important to ask whether there is a simple mechanism to generate spike trains with arbitrarily complex timing patterns. In our work reported in [3.43] and [3.45] we have examined this problem via the use of Van der Pol networks. Complexity of spike trains generated with three, four and five oscillators were examined in detail in these papers.

(d) Circadian Rhythm

Mammalian circadian rhythm is controlled in an area of the brain referred to as the Suprachiasmatic Neucleus (SCN), an area containing 16,000 oscillating neurons. Individually, these neurons act as clocks with roughly 24.3 hour period with a standard deviation of one hour. These cells have the remarkable ability to go into synchronized (i.e. same period), phase-locked oscillations with a time constant of about 4 days. In our work we studied the mathematical aspects of this synchronization phenomena using bifurcation theory of systems with symmetry. Papers [3.45] and [3.47] contain reports of this research.

9. *Other Work*

(a) Control Problems for Advanced Aircraft In collaborative work with the Grumman Aircraft Corporation, a graduate student under my co-supervision, John Reilly, developed control software based on a nonlinear model following control scheme. Technical papers based on this work were presented at the AIAA conference on Guidance, Navigation and Control, held in New Orleans, in August, 1992, and at a workshop on nonlinear control theory, held at Washington University in St. Louis, in August, 1992.

(b) Transient Analysis of Synchronous Motors with Multiple Stator Windings.

In Collaborative work with Westinghouse corporation we analyzed the transient performance of a novel synchronous motor under design using the generalized theory of machines. Software developed were provided to westinghouse corporation for further study.

10. *Current Research Interests*

Current research interests include the areas listed in 4, 8, and in the system theoretic aspects of modeling the dispersal of biological/chemical agents. In the stabilization problem I am primarily interested in systems that undergo switching. In 8 my current research interests span all four subareas listed above. In the dispersal of hazardous material problem we are interested in model reduction approaches using Karhunen-Loeve decomposition and use the reduced order model for studying control aspects.

Teaching

I have taught the following courses.

Texas Tech University: 1986-1989

Math 1350: Analytic Geometry

Math 3350: Higher Mathematics for Engineers and Scientists

Math 1330: Introduction to Mathematical Analysis I

Math 5343: Advanced Topics in Analysis II

Math 5311: Principles of Classical Applied Analysis II

Math 1351: Calculus I

Math 5340: Functional Analysis I

Math 1352: Calculus II

Math 5341: Functional Analysis II

Math 3354: Differential Equations I

Math 1352: Calculus II

Math 4354: Differential Equations II

University of Maryland, College Park: 1989-1996

ENEE 769 B: Advanced Nonlinear Control

ENEE 663: System Theory

ENEE 608 C: Control Theory Seminar

ENEE 460: Control Systems

ENEE 664: Optimal Control

ENEE 663: Nonlinear Systems

ENEE 418 A, B: Walking Machines

Texas Tech University: 1996-

Math 1351: Calculus I

Math 1352: Calculus II

Math 1552: Precalculus

Math 2350: Calculus III

Math 3354: Differential Equations I

Math 4354: Differential Equations II

Math 5310: Principles of Classical Applied Analysis

Math 5312: Control Theory I

Math 5313: Control Theory II

Math 5322: Functions of a Real Variable I

Math 5323: Functions of a Real Variable II