



Martin David ADAMS

BA(Hons), Oxford, MA, Oxford, D.Phil (PhD), Oxford

Associate Professor

School of Electrical & Electronic Engineering /

Division of Control & Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S2.2-B2-23, Singapore 639798

Phone: 6790 4361

E-mail: eadams@ntu.edu.sg

MAJOR RESEARCH INTERESTS / CURRENT RESEARCH

With the aim of multi-sensor based outdoor navigation, our current research interests include the interpretation of sensor data such as millimetre-wave RADAR, 3D-scanning LADAR, strap-down inertial navigation (INS), GPS and visual data. These data sources, provide their information at significantly different rates. This information is synchronized and processed in a sensor fusion based SLAM framework with the aim of robust, outdoor autonomous navigation.

Our research projects aim to produce demonstrations of vehicles which can intelligently navigate in semi-structured outdoor environments, such as theme parks. Demonstrations which show applications such as autonomous vehicle road cleaning and surveillance are currently underway. The particular research issues being addressed to achieve these aims are, algorithmic problems, such as large scale loop closing issues in SLAM, feature rich representations of outdoor scenes to aid the data association process and other techniques such as scan matching of data.

Further the issues of a GPS aided INS navigation system are also being analysed in which vehicle constraints aid the navigation process.

RECENT REPRESENTATIVE PUBLICATIONS

1. M. D. Adams, *Sensor Modelling, Design and Data Processing for Autonomous Navigation*, World Scientific Publishing Co. Ltd., Singapore, 255 pages, 15 February 1999.
2. M. D. Adams, "Active Sensors for Local Planning in Mobile Robotics", Chapter title "AMCW LIDAR Range Acquisition", World Scientific Publishing Co. Ltd, Editor: Penelope Probert Smith, December 2001.
3. Ebi Jose and Martin Adams, "Millimetre Wave RADAR Spectra Simulation and Interpretation for Outdoor SLAM" IEEE International Conference on Robotics & Automation, New Orleans, USA, 2004.
4. Fan Tang, Martin Adams, Javier Ibanez-Guzman and Sardha Wijesoma, "Pose Invariant, Robust Feature Extraction from Range Data with a Modified Scale Space Approach" IEEE International Conference on Robotics & Automation, New Orleans, USA, 2004.
5. Lochana Perera, Sardha Wijesoma and Martin Adams, "On Multidimensional Assignment Data Association for Simultaneous Robot Localisation and Mapping" IEEE International Conference on Robotics & Automation, New Orleans, USA, 2004.
6. Sen Zhang, Lihua Xie and Martin Adams, "An Efficient Data Association Approach to Simultaneous Localization and Map Building" IEEE International Conference on Robotics & Automation, New Orleans, USA, 2004.
7. Martin Adams, Sen Zhang and Lihua Xie, "Particle Filter Based Outdoor Robot Localization using Natural Features Extracted from Laser Scanners" IEEE International Conference on Robotics & Automation, New Orleans, USA, 2004.
8. M. D. Adams and A. J. Kerstens, "Tracking Naturally Occurring Indoor Features in 2D and 3D with Lidar Range/Amplitude Data", *International Journal of Robotics Research*, Vol. 17, No. 9, pp. 907-923, September 1998.
9. M. D. Adams, "Lidar Design, Use and Calibration Concepts for Correct Environmental Detection", *IEEE Transactions on Robotics and Automation*, Vol. 16, No. 6, pp. 753-761, December 2000.
10. M. D. Adams, "Coaxial Range Measurement – Current Trends for Mobile Robotic Applications", *IEEE Sensors Journal*, Vol. 2, No. 1, pp. 2-13, February 2002 - Invited Paper.

POSSIBLE / CURRENT RI PARTNERS AND PROJECTS

A Star Project: "Collaborative Autonomous Systems for Built Environments (CARSyB)", Project Number: 0421010017. Partners include SIMTech and NUS.

AcRF Project: "Fusion of RADAR/LADAR data for Outdoor Feature Extraction, Matching and Localisation", Project Number RG10/01.

SIMTech - NTU Collaborative Research Project: "Feature Based Navigation for Outdoor Terrain Vehicles", Project started Sept 2001



CAI Wenjian

PhD (Oakland University)

Associate Professor

**School of Electrical and Electronics Engineering/
Division of Control & Instrumentation**

Nanyang Technological University

50 Nanyang Avenue, S1-B2a-08, Singapore 639798

Phone: 6790 6862

E-mail: ewjcai@ntu.edu.sg

MAJOR RESEARCH INTERESTS / CURRENT RESEARCH

Dynamic system modelling, control and optimization; Plantwide control for HVAC and environmental system; Intelligent sensing and control technologies; Multi-model and Adaptive control.

RECENT REPRESENTATIVE PUBLICATIONS

1. Lu Lu, Wen-jian Cai, Yeng Chai Soh, Lihua Xie and Shujiang Li "HVAC System Optimization-Condenser Water Loop", *Energy Conversion and Management*, Volume 45, Issue 4, pp. 613-630, March 2004.
2. Yaowen Wang, Wen-jian Cai, Yengchai Soh, Shujiang Li and Lihua Xie, "A simplified modeling of cooling coils for control and optimization of HVAC systems", *Energy Conversion and Management*, Volume 45, Issues 18-19, pp. 2915-2930, 2004.
3. He Maojun and Wen-jian Cai, "A New Loop Pairing Criterion for Multivariable Processes", *Industrial and Engineering Chemistry Research*, in press.
4. Lu Lu, Wen-jian Cai, Yeng Chai Soh and Lihua Xie, "Global optimization for overall HVAC systems-Part I problem formulation and analysis", *Energy Conversion and Management*, in press.
5. Lu Lu, Wen-jian Cai, Yeng Chai Soh and Lihua Xie, "Global optimization for overall HVAC systems- Part II problem solution and simulations", *Energy Conversion and Management*, in press.
6. Lu Lu, Wen-jian Cai, Yengchai Soh, Lihua Xie and Shujiang Li, "HVAC System Optimization-In-Building Section", *Energy and Building*, in press.
7. Shao-Yuan Li, Wen-Jian Cai, Mei Hua and Xiong Qiang, "Robust Decentralized Parameter Identification for Two-input Two-output Process from Closed-loop Step Responses", *IFAC Journal of Control Engineering Practice*, in press.
8. Ming He, Wen-Jian Cai and Shao-Yuan Li, Multiple Fuzzy "Model-based Temperature Predictive Control of HVAC Systems", *Information Sciences*, USA, in press.
9. Sihai Song, Wen-Jian Cai, and Ya-Gang Wang, "Auto-tuning of Cascade Control Systems", *ISA Transaction*, USA, Vol. 42, No. 1, 2003.
10. Wang, Ya-Gang and Wen-Jian Cai, "Decentralised relay-based multivariable process identification in the frequency domain", *IEEE Transactions on Automatic Control*, 2003. Vol. 48, No. 5, pp. 873-877, 2003.

POSSIBLE / CURRENT RI PARTNERS AND PROJECTS

Li-Hua Xie and Wne-Jian Cai, Development of Soft-Sensing Technologies for Chemical Waste Treatment (Purechem Onyx Pte Ltd)

Wne-Jian Cai and Yeng-Chai Soh, Technical Development of Multi-split Inverter Room Air-conditioners in Singapore, (National Environmental Agency)

Wen Changyun, Li-Hua Xie and Wne-Jian Cai Development of Steam Ejector Heat Pumps from Automobile Exhaust Heat Sources, (National Environmental Agency).



CHEAH Chien Chern

PhD MEng Nan. Tech., BEng NUSingapore

Associate Professor

School of Electrical & Electronic Engineering /

Division of Control & Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S1-B1b-53, Singapore 639798

Phone: 6790 5385

E-mail: ECCCheah@ntu.edu. sg

MAJOR RESEARCH INTERESTS

Robotics; Vision-based Control; Underwater robot control; Learning Control.

RECENT REPRESENTATIVE PUBLICATIONS

1. Cheah C.C., Kawamura S. and Arimoto S., "Stability of Hybrid Position and Force Control for Robotic Manipulator with Uncertain Kinematics and Dynamics", *Automatica*, Vol 39, No. 5, 847 - 855,2003.
2. Cheah C.C., "Task-space Feedback Control with Approximate Actuator Model", *Robotica*, Vol. 21, No. 1,95-104,2003.
3. Yazarel H. and Cheah C.C. "Task-space Adaptive Control of Robotic Manipulators with Uncertainties in Gravity Regressor Matrix and Kinematics", *IEEE Transactions on Automatic Control*, Vol. 47, No. 9, 1580-1585, Sept 2002.
4. Yazarel H., Cheah C.C. and H.C. Liaw, "Adaptive SP-D Control of Robotic Manipulators in the presence of Modeling Error in a Gravity Regressor Matrix: Theory and Experiment" *IEEE Transactions on Robotics and Automation*, Vol 18, No. 3, 373 - 379, June 2002.
5. Cheah C.C., "Robustness of Time-scale Learning of Robot Motions to Uncertainty in Acquired Knowledge" *Journal of Robotic System*, Vol. 18, No. 10, 599-608, October 2001.
6. Cheah C.C., Kawamura S. and Arimoto S. and K. Li, "H-infinity Tuning for Task-Space Feedback Control of Robot with Uncertain Jacobian Matrix", *IEEE Transactions on Automatic Control*, Vol 46, No. 8, pp 1313-1318, August 2001.
7. Cheah C.C., "Comments on Direct Learning of Control Efforts for Trajectories with Different Time Scales", *IEEE Transactions on Automatic Control*, vol. 45, No. 6, pp 1214-1215,2000.
8. Kino H., Yabe S., Cheah C.C., Kawamura S. and Arimoto S., "A Motion Control Scheme in Task Oriented Coordinates and its Robustness for Parallel Wire Drive Systems", *Journal of Robotics Society of Japan*, vol. 18, No. 3, pp 411-418,2000.
9. Arimoto S., Han H.Y., Cheah C.C. and Kawamura S., "Extension of Impedance Matching to Nonlinear Dynamics of Robot Tasks", *System and Control Letters*, vol. 36, No. 2, pp 109-119, 1999.
10. Cheah C.C., Kawamura S. and Arimoto S. "Feedback Control for Robotic Manipulators with an Uncertain Jacobian Matrix", *Journal of Robotic System*, vol. 12, No. 2, pp 119-134, 1999.
11. Cheah C.C. and Wang D., "Learning Impedance Control for Robotic Manipulator," *IEEE Transactions on Robotics and Automation*, vol. 14, No. 3, pp 452-465,1998.
12. Wang D. and Cheah C.C., "An Iterative Learning Control Scheme for Impedance Control of Robotic Manipulator," *International Journal of Robotic Research*, Vol 17, No. 10,pp1091-1103, 1998.
13. Cheah C.C. and Wang D., "Discrete-Time Model Reference Learning Control: Theory and Experiment," *Dynamics and Control*, Vol 8, No. 2, pp 1-22,1998.
14. Cheah C.C. and Wang D., "A Model Reference Learning Control Scheme for a Class of Nonlinear Systems," *International Journal of Control*, Vol. 66, No. 2, pp 271-287, 1997.
15. Cheah C.C. and Wang D., "Learning Control for a Class of Nonlinear Differential-Algebraic Systems with Application to Constrained Robots," *Journal of Robotic Systems*, Vol. 13, No. 3, pp 141-151,1996.
16. Cheah C.C., Wang D., and Soh Y.C., "Learning Control of Motion and Force for Constrained Robotic Manipulators," *International Journal of Robotics and Automation*, Vol. 10, No. 3, pp 79-88, 1995.
17. Wang D., Soh Y.C., and Cheah C.C., "Robust Motion and Force Control of Constrained Manipulators By Learning," *Automatica*, Vol. 31, No. 2, pp 257-262, 1995.
18. Cheah C.C., Wang D., and Soh Y.C., " Convergence and Robustness of A Discrete-Time Learning Control Scheme for Constrained Manipulators," *Journal of Robotic Systems*, Vol. 11, No. 3, pp 223-238, 1994.



CHUA Chin Seng

PhD Monash, BEng (Hons) NU Singapore

Associate Professor

School of Electrical & Electronic Engineering /

Division of Control & Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S1-B1c-81, Singapore 639798

Phone: 6790 5412

E-mail: ecschua@ntu.edu.sg

MAJOR RESEARCH INTERESTS

Dr Chua Chin Seng graduated with B.Eng (Honours) (1987-1990) from Nanyang Technological University and Ph.D. (1992-1995) in Computer Vision from Monash University, Australia. He has attained several honours, including two gold medals (IES and Institute of Consulting Eng) for his undergraduate studies, as well as two scholarships from the Federal Government of Australia for his postgraduate work. His industrial experiences include working with Hewlett Packard Singapore as a System Engineer (1986-1987, 1990-1992) and with Defence Science Organisation (1995-1997) as a Research Engineer. Two MINDEF projects (classified) on computer vision were completed during his stay with DSO. Dr Chua joined the University as an academic staff in 1997 and since then has been involved in the several projects in tracking and surveillance using Computer Vision (see below). Other research interests would include face recognition and detection, activity recognition and deformable shape matching.

Localisation and Identification of 3D Objects Using Computer Vision (Principal Investigator) (completed in 2002). This is an AcRF funded project of 3 years, with a funding amount of \$100,000. This project is concerned with the recognition of 3D objects such as complex, free-forming objects, non-rigid objects or terrain matching.

Vehicle Tracking and Surveillance (Principal Investigator) (on-going). This project is co-funded by DSO and NTU for 2 years, with a funding amount of \$396,200. The objective of this project is to track vehicles against various scenarios of occlusion, loss of track and tracking using an unstable platform.

RECENT REPRESENTATIVE PUBLICATIONS

1. C.S. Chua, Y. Ren, Y.K. Ho, "Motion Detection with Non-stationary Background", *Int'l J. Machine Vision and Applications*, 13:332-343, 2003.
2. C. S. Chua, H. Y. Guan, Y. K. Ho, "Model-based 3D Hand Posture Estimation From A Single 2D Image", *Int'l J. Image Vision Computing*, 20(3): 191-202, Feb 2002.
3. Y. Ren, C. S. Chua, Y. K. Ho, "Motion Detection From Time-Varied Background", *Int'l J. Image Graphics (Special Issue)*, 2(2):163:178, 2002.
4. Y. Wang, C. S. Chua, Y. K. Ho, "Facial Feature Detection And Face Recognition From 2D and 3D Images", *Pattern Recognition Letters*, 23(10): 1191-1202, May 2002.
5. Y. Ren, C.S. Chua, Y.K. Ho, "Motion Detection from Time-varied Background", *ACCV 2002*, Melbourne, Australia, pp. 222-227 (Best paper), 2002.
6. Z. Zhou, H. Liu, S. Li, C. S. Chua, "Rule Mining With Prior Knowledge – A Belief Networks Approach", *Int'l J. Intelligent Data Analysis*, 5:95-110, 2001.
7. C. S. Chua, Y. K. Ho, Y. Liang, "Rejection Of Mismatched Correspondences Along the Affine Epipolar Line", *Int'l J. Image Vision Computing*, 18(6):445-462, March 2000.
8. C. S. Chua, R. A. Jarvis, "Point Signatures: A New Representation For 3D Object Recognition", *International Journal Computer Vision*, 25(1):63-85, 1997.
9. C. S. Chua, R. A. Jarvis, "3D Free-Form Surface Registration and Object Recognition", *International Journal Computer Vision*, 17(1):77-99, 1996.



ER Meng Joo

B.Eng (Hons), M. Eng, (NUS), Ph.D (ANU)

Director, Intelligent Systems Centre

Nanyang Technological University

**50, Nanyang Drive, 7th Storey, Research TechnoPlaza, BorderX Block,
Singapore 637533**

Phone: 6790 6850 Fax: 6316 2065

E-mail: emjer@ntu.edu.sg

MAJOR RESEARCH INTERESTS

Control theory and applications; Fuzzy systems and neural networks; Artificial intelligence and machine learning; Robotics and automation; Face recognition and detection; Biomedical engineering; Digital signal processing; Speech recognition; Power electronics and drives.

RECENT REPRESENTATIVE PUBLICATIONS

Book

M.J. Er, S.Q. Wu, and Y. Gao, "Dynamic Fuzzy Neural Networks: Algorithms, Architectures and Applications," published by McGraw Hill, 2003.

Book Chapters

1. M. J. Er and Y. Gao, "Online Adaptive Fuzzy Neural Identification and Control of Nonlinear Dynamic Systems," in *Fusion of Soft Computing and Hard Computing for Autonomous Robotic Systems* edited by C. Zhou, D. Maravall and D. Ruan, New York, Heidelberg: Physica-Verlag, pp. 373-402, 2003
2. M. J. Er and Y. L. Sun, "Hybrid Fuzzy Proportional-Integral plus Conventional Derivative Control of Robotics Systems," in *Fusion of Soft Computing and Hard Computing for Autonomous Robotic Systems* edited by C. Zhou, D. Maravall and D. Ruan, New York, Heidelberg: Physica-Verlag, pp. 403-450, 2003.
3. M. J. Er and W.K. Lim, "Classification of Breast Cancers Using Dynamic Fuzz Neural Networks," in *Intelligent Sensory Evaluation-Methodologies and Applications*, edited by D. Ruan, Chapter 19, Springer, 2003.
4. M.J. Er, S.Q. Wu and W.L. Chen, "Face Recognition Using a RBF Neural Classifier with Hybrid Learning," to appear in *Intelligent Sensory Evaluation* edited by D. Ruan and Xianyi Zeng, Springer, 2003.
5. Y. Gao and M.J. Er, "Adaptive Modelling and Control of Drug Delivery Systems Using Dynamic Fuzzy Neural Networks," to appear in *Intelligent Sensory Evaluation* edited by D. Ruan and Xianyi Zeng, Springer, 2003.

Journal Papers

1. S.Q. Wu, M. J. Er and Y. Gao, " A Fast Approach for Automatic Generation of Fuzzy Rules by Generalized Dynamic Fuzzy Neural Networks," *IEEE Trans. on Fuzzy Systems*, USA, Vol. 5, No. 4, pp. 578-594, August 2001.
2. M.J. Er and Y. Sun, "Hybrid Fuzzy Proportional-Integral plus Conventional Derivative Control of Linear and Nonlinear Systems," *IEEE Trans on Industrial Electronics*, Vol. 48, No. 6, pp. 1109 - 1117, December 2001.
3. M. J. Er and S.Q. Wu, "A Fast Learning Algorithm for Parsimonious Fuzzy Neural Systems," *Fuzzy Sets and Systems*, Vol. 126/3, pp. 61-75, 2002.
4. M.J. Er, S.Q. Wu, J.W. Lu and H.L. Toh, "Face Recognition Using Radial Basis Function (RBF) Neural Networks", *IEEE Trans. on Neural Networks*, Vol. 13, No. 3, pp. 697-710, May 2002.
5. M.J. Er and Y. Gao, "Robust Adaptive Control of Robot Manipulators Using Generalized Dynamic Fuzzy Neural Networks, *IEEE Transactions on Industrial Electronics*, Vol. 50, No.3, pp. 620-628, June 2003.
6. Y. Gao and M.J. Er, "Online Adaptive Fuzzy Neural Identification and Control of a Class of MIMO Nonlinear Systems," *IEEE Trans. on Fuzzy Systems*, Vol. 11, No. 4, pp. 462-477, August 2003.
7. M.J. Er, and C. Deng "Online Tuning of Fuzzy Inference Systems Using Dynamic Fuzzy Q-Learning," accepted for publication in *IEEE Trans on Systems, Man and Cybernetics, Part B*.



LING Keck Voon

DPhil(Oxf)

Associate Professor

School of Electrical & Electronic Engineering /

Division of Control & Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S2-B2a-22, Singapore 639798

Phone: 6790 5567

E-mail: ekvling@ntu.edu.sg

Website: <http://www.ntu.edu.sg/home/ekvling>

MAJOR RESEARCH INTERESTS

- Control Theory and applications, especially Model Predictive Control for high-bandwidth, embedded control applications
- Medical image analysis and image registration, especially prostate outlining from ultrasound images

I am currently embarking on the project entitled "Model Predictive Control on a Chip" funded by the ASTAR Embedded and Hybrid Strategic Research Programme. This project was motivated by the trend in miniaturisation of machines which traditionally occupy a large volume space into chip scale level. There will be increasing demands for sophisticated control systems to be embedded into these micro machines to achieve integrated "laboratory on a chip" or even "factory on a chip" devices. A case in point is the concept of a biochip for biological and chemical analysis. Model Predictive Control, or MPC as it is sometimes known, is our candidate control technology to be encapsulated in suitable modules for embedded control.

RECENT REPRESENTATIVE PUBLICATIONS

Model Predictive Control

1. KV Ling, MH He, BF Wu, Y Zhang, An Augmented Model Predictive Controller for Multirate Cascade Systems, American Control Conference, Boston, USA, pp.1575-1579, 30 June - 2 July 2004.
2. KV Ling, P. Falugi, JM Maciejowski and L Chisci, Robust Predictive Control of the Furuta Pendulum, 15th IFAC World Congress, Barcelona, Spain, July 2002
3. Ling KV and Lim KW, Receding Horizon Recursive State Estimation, IEEE Transactions on Automatic Control, Vol.44, No.9, pp.1750-1753, 1999.
4. Low KS, Chiun KY and Ling KV, Evaluating Generalised Predictive Control for a Brushless DC Drive, IEEE Trans. on Power Electronics, Vol 13, No 6, pp 1191-1198, November 1998.
5. Lim KW, Ho WK, Lee TH, Ling KV and Xu W. Generalized Predictive Controller With Pole-Restriction, IEE Proc. Pt D., Vol.145, No.2, pp.219-225, March 1998.
6. Ling KV and Lim KW. A State Space GPC with Extension to Multi-Rate Control. Automatica, Vol.32, No.7, pp.1067-1071, 1996.

Prostate Outlining, Image Registration

7. Shao F, Ling KV and Ng WS, "Automatic 3D Prostate Surface Detection from TRUS with Level Sets", Special Issue on "Deformable Models for Image Analysis and Pattern Recognition", International Journal of Image and Graphics, Vol.4, No.3, pp.1-19, 2004.
8. Shao F, Ling KV, Ng WS and Wu RY, Prostate boundary detection from ultrasonographic images, Journal of Ultrasound in Medicine, Vol.22, pp.605-623, 2003.
9. Wu RY, Ling KV, Shao W and Ng WS, Registration of Organ Surface with Intra-operative 3D Ultrasound Image Using Genetic Algorithm, in R.E. Ellis and T.M. Peters (Eds.): MICCAI 2003, LNCS 2878, pp.383-390, 2003.
10. F. Shao, K.V. Ling and W.S. Ng, A Practical Method for Prostate Surface Detection from 3D TRUS, Proceedings of World Congress on Medical Physics and Biomedical Engineering, Sydney, Australia, August 2003.
11. Tian X, Ling KV and Ng WS, Magnetic tracker calibration for augmented reality system for therapy, Proc Institution of Mechanical Engineers, Part H, Vol.215, pp.51-60, 2001
12. Wu RY, Ling KV and Ng WS, Automatic prostate boundary recognition in sonographic images using feature model and genetic algorithm, Journal of Ultrasound in Medicine, Vol.19, pp.771-782, 2000



LOW Kay Soon

Ph.D., U.N.S.W., B.Eng. (Hons), N.U.S., SrMIEEE

Associate Professor

School of Electrical & Electronic Engineering /

Division of Control & Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S2-B2c-118A, Singapore 639798

Phone: 6790 4003

E-mail: ekslow@ntu.edu.sg

MAJOR RESEARCH INTERESTS

My research interests focus on several areas. One area is the intelligent control and management of sensor network that integrate sensors, microcontrollers, FPGA, wireless technology and network protocol etc for remote monitoring and control. Several subsystems have been completed by the students in the laboratory. It has a wide range of applications such as security and environmental monitoring, warehouse tracking etc. A second area is biometric signal processing such as the speech processing and palm vein recognition. Several projects are currently in progress and are in collaboration with the Institute of Infocomm Research. Another area involves the ultra wide-band communication system and radar for ranging and through wall imaging applications. A number of prototypes have been developed for transmitting high quality compact disc music and DVD video in real time wirelessly. I also have research students worked on high precision control of linear motor drive that can achieve accuracy of better than 1 μm . Laboratory prototypes of linear stage and xy table have been developed for vision inspection, laser cutting applications etc. Other research areas include high performance nonlinear control of electronics and power converters used in applications such as UPS, satellite solar power system, and digital communications etc.

RECENT REPRESENTATIVE PUBLICATIONS

1. **Advanced Precision Linear Stage for Industrial Automation Applications**
Kay-Soon Low, Meng-Teck Keck, IEEE Transaction on Instrumentation & Measurements, Vol. 52, No. 3, June 2003, pp 785-789.
2. **Method and apparatus for multi-level phase shift keying communications**
Kay Soon Low, Kin Mun Lye, Kar Ming Ho, PCT Patent, WO03049394A1, 12 June 2003
3. **Method and apparatus for ultra wide-band communication system using multiple detectors**
Kay Soon Low, Kin Mun Lye, Paul Kar Ming Ho, PCT Patent, WO03030388A1, 10 April 2003
4. **Method and apparatus for generating pulses using dynamic transfer characteristics**
Kay Soon Low, Jurianto Joe, US Patent, US6498578, 24 December 2002.
5. **Method and apparatus for signal detection in ultra wide-band communications**
Kay Soon Low, Jurianto Joe, US Patent US6456221, 24 September 2002.
6. **Digital control of a permanent magnet synchronous motor drive without mechanical sensors**
Y Deng, K S Low and X Guo, International Journal on Electric Power Components and Systems, Vol. 29, No.5, May 2001, pp. 459-477.
7. **Periodic errors elimination in CVCF PWM DC/AC converter systems: Repetitive control approach**
K. Zhou, D. Wang and K. S. Low, IEE Proceedings - Control Theory and Applications, November 2000, Vol. 147, Issue 6, pp.694-700.
8. **Robust model predictive control and observer for direct drive applications**
K S Low and H. Zhuang, IEEE Transactions on Power Electronics, Vol. 15, No. 6, Nov 2000, pp. 1018-1028.
9. **A high performance linear stage using predictive control and genetic algorithms**
K S Low and M T Keck, In "Recent Advances in Mechatronics", Eds. O. Kaynak etc., Springer-Verlag 1999, pp. 232-244.
10. **A digital signal processor based single phase AC power source using generalized predictive control**
K S Low, IEEE Transactions on Industrial Electronics, Vol. 46, No. 5, October 1999, pp 936-941.

POSSIBLE / CURRENT RI PARTNERS AND PROJECTS

1. Institute for Infocomm Research, Dr Yau Wei Yun, Digital signal processing and analysis of speech and image data
2. SIMTech, Dr Lin Wei, Precision control of linear drive and piezo actuator
3. DSI, Advanced control and signal processing of data storage system



P. N. SUGANTHAN

BA, MA (U of Cambridge, UK) PhD (NTU)

Associate Professor

School of Electrical and Electronic Engineering /

Division of Control & Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S2-B2a-21, Singapore 639798

Phone: 6790 5404

E-mail: epnsugan@ntu.edu.sg

MAJOR RESEARCH INTERESTS / CURRENT RESEARCH

Evolutionary computation (EA), Particle swarm optimization (PSO), Genetic algorithms (GA), Applications of PSO/GA/EA in photonic FBG filter design, microwave antenna design, filterbank design, feature analysis, etc. Bioinformatics, Biomedical image analysis, Pattern recognition and Neural networks.

RECENT REPRESENTATIVE PUBLICATIONS

1. Qin AK, Suganthan PN (2004) Robust growing neural gas algorithm with application in cluster analysis. Neural Networks - special issue on Recent Developments in Self-Organizing Systems.
2. Atukorale AS, Downs T, Suganthan PN (2003) Boosting HONG Networks. Neurocomputing 51:75-86.
3. Khoo KG, Suganthan PN (2003) Structural Pattern Recognition using Genetic Algorithms with Specialised Operators. IEEE T. on Systems, Man and Cybernetics - B USA, 33(1):156-165.
4. Suganthan PN (2002) Structural pattern recognition using genetic algorithms. Pattern Recognition 35(9):1883-1893, UK.
5. Suganthan PN (2001) Pattern classification using multiple hierarchical overlapped self-organising maps. Pattern Recognition 34:173-2179, UK.
6. Suganthan PN, Teoh EK, Mital DP (1995) Pattern recognition by graph matching using the Potts mean field theory network. Pattern Recognition 28(7):997-1009.
7. Liang JJ, Qin AK, Suganthan PN, Baskar S, (2004) Multi-exemplars Particle Swarm Optimization Algorithm. 11th Int. Conf. on Neural Information Processing, Calcutta, India, Nov., 2004.
8. Tang EK, Suganthan PN, Yao X (2004) Nonlinear Feature Extraction Using Evolutionary Algorithm. 11th Int. Conference on Neural Information Processing, Calcutta, India, November.
9. Shi SYM, Suganthan PN, Deb K (2004) Multiclass protein fold recognition using multi-objective evolutionary algorithms. IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology, La Jolla, San Diego, USA, October.
10. Baskar S, Alphones A, Suganthan PN (2004) Concurrent PSO and FDR-PSO based reconfigurable Phase-Differentiated Antenna Array Design. Congress on Evolutionary Computation, June, Oregon, Portland, USA.



SOH Yeng Chai

PhD

Professor

**School of Electrical & Electronic Engineering /
Division of Control & Instrumentation**

Nanyang Technological University

50 Nanyang Avenue, S2-B2a-17, Singapore 639798

Phone: 6790 5423

E-mail: eycsoh@ntu.edu.sg

Yeng Chai SOH received the B.Eng. (Hons. I) degree in electrical and electronic engineering from the University of Canterbury, New Zealand, in 1983, and the Ph.D. degree in electrical engineering from the University of Newcastle, Australia, in 1987. From 1986 to 1987, he was a research assistant in the Department of Electrical and Computer Engineering, University of Newcastle. He joined the Nanyang Technological University, Singapore, in 1987 where he is currently a professor in the School of Electrical and Electronic Engineering. Since 1995, he has been the Head of the Control and Instrumentation Division. He is an honorary professor of Northeastern University and an adjunct professor cum part-time doctoral adviser of Harbin Institute of Technology.

MAJOR RESEARCH INTERESTS

System Theory and Applications; Estimation and Signal Processing; Optical Signal Processing for Communications and Measurements; Secure Communication Systems; Control of Networks

RECENT REPRESENTATIVE PUBLICATIONS

Eg. (Selected publication from 2000 onwards. Total is more than 150 refereed international journal papers)

1. Z. Tan, Y. C. Soh and L. Xie, "Dissipative Control of Linear Discrete-time Systems with Dissipative Uncertainty", *International Journal of Control* (U.K.), Vol. 75, No. 4, pp. 317-328, 2000.
2. Z. Tan, Y. C. Soh and L. Xie, "Envelope-constrained H-infinity Filter Design: An LMI Optimization Approach", *IEEE Trans. Signal Processing* (U.S.A.), Vol. 48, No. 10, pp. 2960-2963, 2000.
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8. K. Li, and Y. C. Soh and Z. G. Li, "Chaotic Cryptosystem with High Sensitivity to Parameter Mismatch," *IEEE Trans. Circuits & Systems Part I* (U.S.A.), Vol. 50, pp. 579-583, 2003.
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10. H. Zhang, L. Xie and Y. C. Soh, "Risk-Sensitivity Filtering, Prediction and Smoothing for Discrete Singular Systems," *Automatica* (U.K.), Vol. 39, No. 1, pp. 57-66, 2003.
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12. K. Li, and Y. C. Soh and Z. G. Li, "Synchronization of Lorenz Systems via Impulsive Control and Sporadic Coupling," *Int. J. of Bifurcation and Chaos* (U.S.A.), accepted for publication, 2003.
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14. H. Zhang, L. Xie Y. C. Soh and W. Wang, "Optimal and Self-Tuning State Estimation for Singular Stochastic Systems: A Polynomial Equation Approach," *IEEE Trans. Circuits & Systems Part II* (U.S.A.), Vol. 51, No. 6, pp. 327-333, 2004.
15. P. H. Lee and Y. C. Soh, "Simultaneous H-infinity Stabilization," *Int. J. Control* (U.K.), Vol. 77, No. 2, pp. 111-117, 2004.



WANG Danwei

PhD University of Michigan, Ann Arbor, US

Associate Professor

School of Electrical & Electronic Engineering /

Division of Control & Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S2-B2b-50, Singapore 639798

Phone: 6790 5376

E-mail: edwwang@nus.edu.sg

MAJOR RESEARCH INTERESTS

Associate Professor Wang Danwei is actively involved in teaching and research related to robotics and control. He has successfully completed the AcRF projects "Development of learning control algorithms for dynamic systems performing repetitive operations", and "Navigation and control of a fleet of computer-aided mobile systems", and is a collaborator for several projects in robotics research. Dr Wang has been working on the outdoor mobile robotics since 1995 and was involved in a collaboration project with PSA. He has published more than 140 technical papers and articles in international refereed journals and academic conferences in the areas of robotic manipulators, control design, intelligent systems, learning control, mobile robotics, mobile robot path and trajectory planning, experimental implementations and applications.

RECENT REPRESENTATIVE PUBLICATIONS

1. Wang, Danwei, "On D-Type and P-Type ILC Designs and Anticipatory Approach", Special Issue on Iterative Learning Control, *International Journal of Control*, Vol.73 No.10,2000, pp.890 - 901.
2. Ye, Cang, and Wang, Danwei, "A novel navigation method for autonomous mobile vehicles", *Journal of Intelligent and Robotic Systems*, vol. 32 no. 4, Dec. 2001, pp.361-388.
3. Ye, Cang, Yung, H.C., and Wang, Danwei, "A fuzzy controller with supervised learning assisted reinforcement learning algorithm for obstacle avoidance" *IEEE Transactions on Systems, Man, and Cybernetics-Part B: Cybernetics*, Vol. 33, No. 1,2003, pp. 17-27.
4. Sun, Mingxuan, and Wang, Danwei, "Initial shift issues on discrete-time iterative learning control with systems relative degree", *IEEE Transactions on Automatic Control*, Vol. 48, No.1, January 2003, pp. 144-148.
5. Zhou, Keliang, and Wang, Danwei, "Digital repetitive control for CVCF PWM Converters", *IEEE Trans on Power Electronics*, Special Issue on Digital Control, Vol.18, No.1, January 2003, pp. 309-316.
6. Wang, Danwei, and Xu, Guangyan, "Full state tracking and internal dynamics of nonholonomic wheeled mobile robots"; *IEEE/ASME Trans on Mechatronics*, Focused Section on Advances in Robot Dynamics and Control, Vol.8, No.2, June 2003.



WANG Han

PhD, Leeds

Associate Professor

School of Electrical & Electronic Engineering /

Division of Control and Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S2-B2b-49, Singapore 639798

Phone: 67904506

E-mail: hw@ntu.edu.sg

Home Page: <http://www.ntu.edu.sg/home/hw>

MAJOR RESEARCH INTERESTS / CURRENT RESEARCH

1. Robotics
2. Machine Vision
3. Surveillance

RECENT REPRESENTATIVE PUBLICATIONS

1. X. Wang and H. Wang. Evolutionary Optimization with Markov Random Field Prior, *IEEE Trans. on Evolutionary Computation*, in print.
2. X. Wang and H. Wang. Markov random field modeled range image segmentation. *Pattern Recognition Letters*, 25:367-375, 2004
3. H. Wang and W. Song. Correction of bias for motion estimation algorithms. *Pattern Recognition Letters*, 23:1505-1514, 2002.
4. Fei Shen and Han Wang. Corner detection based on modified Hough Transform. *Pattern Recognition Letters*. 23(8):1039-1049, June 2002
5. L. Qiu, W. Hsu, S. Huang and H. Wang. Scheduling and routing algorithms for AGVs: a survey. *Int. Journal of Production Research*, 40(3):745—760, 2002
6. Y. Y. Dong and H. Wang. Disparity interpolation for image syntheses. *Pattern Recognition Letters*, 21:201-210, 2000.
7. Y. K. Tham, H. Wang and E. K. Teoh. Multi-sensor fusion for steerable four-wheeled industrial vehicle. *Control Engineering Practice*, 7:1233-1248, 1999.
8. Zheng Li and H. Wang. Real-time 3D motion tracking with known geometric models. *Journal of Real-Time Imaging*, 5(3):167-190, 1999.
9. W. Y. Yau and H. Wang. Fast relative depth computation for an active stereo vision system. *Journal of Real-Time Imaging*, 5(3):191-204, 1999.

POSSIBLE / CURRENT RI PARTNERS AND PROJECTS

Xu Jian *et al* (Simtech), "Hubble" (camera calibration for stereo vision)



WANG Jianliang

PhDJohnsH.

Associate Professor

School of Electrical & Electronic Engineering /

Division of Control & Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S2-B2b-48, Singapore 639798

Phone: 6790 4846

E-mail: ejlwang@ntu.edu.sg

MAJOR RESEARCH INTERESTS

- Reliable and robust control,
- Non-fragile control,
- Nonlinear system and control,
- Aircraft flight simulation and control,
- Fault detection and identification,
- Reliable and robust filtering

RECENT REPRESENTATIVE PUBLICATIONS

1. J. Liu, Jian Liang Wang and G.-H. Yang, "Reliable Guaranteed Variance Filtering with Sensor Faults", *IEEE Transactions on Signal Processing*, Vol. 51, No. 5, pp. 1403-1411, May 2003.
2. J.S. Yee, Jian Liang Wang and Bin Jiang, "Actuator Fault Estimation Scheme for Flight Application", *ASME J. of Dyn. Systems, Measur., and Contr.*, Vol. 124, No. 4, pp. 701-704, December 2002.
3. G.-H. Yang and Jian Liang Wang, "Nonfragile H-infinity Output Feedback Controller Design for Linear Systems", *ASMEJ. of Dyn. Systems, Measur., and Contr.*, Vol. 125, No. 1, pp. 117-123, March 2003.
4. B. Jiang, Jian Liang Wang and Y.C. Soh, "An Adaptive Technique for Robust Diagnosis of Faults with Independent Effects on System Outputs", *Int. J. of Contr.*, Vol. 75, No. 11, pp. 792-802, July 2002.
5. F. Liao, Jian Liang Wang and G.-H. Yang, "Reliable Robust Flight Tracking Control: An LMI Approach", *IEEE Transactions on Control System Technology*, Vol. 10, No. 1, pp. 76-89, January 2002.
6. G.-H. Yang, Jian Liang Wang and Y.C. Soh, "Reliable H-infinity Controller Design for Linear Systems", *Automatica*, Vol. 37, No. 5, pp. 717 - 725, May 2001.
7. G.-H. Yang and Jian Liang Wang, "Non-fragile H-infinity Control for Linear Systems with Multiplicative Controller Gain Variations", *Automatica*, Vol. 37, No. 5, pp. 727 - 737, May 2001.
8. G.-H. Yang and Jian Liang Wang, "Robust Non-fragile Kalman Filtering for Uncertain Linear Systems with Estimator Gain Uncertainty", *IEEE Trans. on Autom. Contr.*, Vol. 46, No. 2, pp. 343 -348, 2001.
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11. J.-S. Yee, G.-H. Yang and Jian Liang Wang, "Resilient Guaranteed Cost Control to Tolerate Actuator Faults for Discrete-time Uncertain Linear Systems", *IEEE Proceedings D: Control Theory and Applications*, Vol. 147, No. 3, pp. 277-284, May 2000.
12. J.-S. Yee, G.-H. Yang and Jian Liang Wang, "Non-Fragile H-infinity Flight Controller Design for Large Bank-Angle Tracking Maneuver", *IME Journal of Systems and Control Engineering*, Vol. 214, Part I, No. 3, pp. 157 — 172, May-June 2000.
13. B. Jiang, Jian Liang Wang and Y.C. Soh, "Robust Fault Diagnosis for a Class of Linear Systems with Uncertainties", *AIAA J. of Guidance and Control*, Vol. 22, No. 5, pp. 736 - 640, 1999.
14. Jian Liang Wang and W.Q. Zhang, "Neuro-Fuzzy Scheduling of H_∞ Robust Controllers for a High Performance Fighter Aircraft under a Herbst-like Maneuver", *Int. J. of Control: Special Issue on "Multiple Model Approaches to Modelling and Control"*, Vol. 72, No. 7/8, pp. 740 - 754, 1999.
15. G.-H. Yang, J. Lam and Jian Liang Wang, "Reliable H-infinity Control for Affine Nonlinear Systems", *IEEE Transactions on Automatic Control*, Vol. 43, No. 8, pp. 1112 -1117, August 1998.
16. G.-H. Yang, Jian Liang Wang, C.B. Soh and J. Lam, "Decentralized H-infinity Controller Design for Nonlinear Systems", *IEEE Trans. on Automatic Control*, Vol. 44, No. 3, pp. 578 - 583, March 1999.



WEN Changyun

PhD Newcastle (NSW)

Associate Professor

School of Electrical & Electronic Engineering /

Division of Control & Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S2-B2b-45, Singapore 639798

Phone: 6790 4947

E-mail: ecywen@ntu.edu.sg

MAJOR RESEARCH INTERESTS:

- Modelling of Bio-Dynamics
- Design of Active Auto-Focus Systems Based on Feedback Control
- 2-D Systems and Image Processing
- Control of Nonlinear Systems with Applications
- Adaptive Control
- Hybrid Systems

RECENT REPRESENTATIVE PUBLICATIONS

1. Yani Zhang, Ying Zhang and C. Wen (2000), A new focus measure method using moments, *Journal of Image and Vision Computing*, U.K., Vol.18, pp959-965.
2. Y. Zhang, C. Wen and Y.C. Soh (2000), Adaptive Backstepping Control Design for Systems with Unknown High Frequency Gain, *IEEE Trans. Auto. Control* U.S.A., Vol. 45, pp2350 - 2354.
3. Y. Zhang, C. Wen and Y.C. Soh (2000), Unbiased LMS Filtering in the presence of White Measurement Noise with Unknown Power, *IEEE Trans. Circuit and Systems Part II U.S.A.*, Vol. 47, No.9 pp968 - 972.
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5. Z. G. Li, C. Wen and Y. C. Soh (2001), Analysis and design of impulsive control systems, *IEEE Trans. Auto. Control*, U.S.A., Vol.46, pp.894-897
6. Z. G. Li, C. Wen and Y. C. Soh (2001), Robust stability of a class of hybrid nonlinear systems,, *IEEE Trans. Auto. Control*, U.S.A., Vol.46, pp.897 - 903.
7. Z. G. Li, Y. C. Soh and C. Wen (2001), Robust stability of quasi-periodic hybrid dynamic uncertain systems, *IEEE Trans. Auto. Control*, U.S.A., Vol. 46, pp107 -111.
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9. Z. G. Li, C. Wen and Y. C. Soh (2001), Switched controllers with applications in bilinear systems,, *Automatica* U.K., Vol.37,pp.477-481.
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12. Z. G. Li, C. Wen and Y. C. Soh (2002), Generalized matrix measure of switched nonlinear systems, *IEEE Trans. Auto.Control*, U.S.A. Vol.47, pp.178—183.
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14. H. Fan and C. Wen (2003), Adaptive Control of a Class of 2-D Discrete System, *IEEE Trans. on Circuits and Systems Part 1*, U.S.A., Accepted for Publication.
15. H. Fan and C. Wen (2003), Two Dimensional Adaptive Filtering Based on Projection Algorithm, *IEEE Trans. On Signal Processing*, U.S.A. Accepted for Publication, Z. G. Li, K. Li, C. Y. Wen and Y. C. Soh (2003), A New Chaotic Secure Communication



Wijerupage Sardha WIJESOMA

PhD (University of Cambridge), BSc. Engrg. Hons, MIEEE, CEng., MBCS

Associate Professor

School of Electrical and Electronic Engineering/

Division of Control & Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S1-B1c-86, Singapore 639798

Phone: 6790 4518

E-mail: eswwijesoma@ntu.edu.sg

MAJOR RESEARCH INTERESTS / CURRENT RESEARCH

My research interests and efforts have been very broad, cross-cutting and synthesize original work in intelligent and autonomous systems including control and navigation of autonomous vehicles, smart vehicles, advanced driver assistance systems (ADAS), and mobile robots, computer vision for tracking and navigation, behaviour-based robotics, simultaneous localization and mapping, perception, sensing and sensor fusion, data association, tracking, system integration for intelligent autonomous systems, object and component based software architectures for intelligent systems. Of late neural interfaces devices based on bio-signals (EEG, EOG and EMG) to aid people with limited peripheral mobility.

RECENT REPRESENTATIVE PUBLICATIONS

1. **W.S. Wijesoma**, K.R.S. Kodagoda, and A. P. Balasuriya, "Road Boundary Detection and Tracking using Ladar", IEEE Trans. Robotics and Automation, Vol. 20, No. 3, June2004.
2. D.L. Perera, **W.S. Wijesoma**, and M.D. Adams, "On Multidimensional Assignment Data Association for Simultaneous Robot Localization and Mapping", Proc. of the Intl. Conf. on Robotics and Automation, ICRA2004, Apr. 26 – May 1, 2004, New Orleans, LA, USA.
3. **W. S. Wijesoma**, K. R. S. Kodagoda, A. P. Balasuriya, and S. Challa, "Road curb tracking in an urban environment", Proc. of the 6th Intl. Conf. on Information Fusion, Australia, July 2003.
4. **W.S. Wijesoma** K.R.S. Kodagoda, and E.K. Teoh, "Stable Fuzzy State Space Controller for Lateral Control of an AGV", J. of VLSI Signal Processing Systems for Signals, Image, and Video Technology, Kluwer Academic Publishers, Vol. 32, Numbers1/2, August-September, pp189-201, 2002.
5. **W. S. Wijesoma**, K.R.S. Kodagoda and A.P. Balasuriya, "A Laser-Vision Sensing for Road Detection and Reconstruction", Proceedings of the IEEE 5th Intl Conf. on Intelligent Transportation Systems (ITSC 2002), Sept. 3-6, 2002, Singapore.
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7. **W. S. Wijesoma**, Khaw Ping Ping, and E. K. Teoh, "Sensor Modeling and Fusion for Fuzzy Navigation of an Outdoor AGV", Int. J. of Robotics and Automation, Vol. 16, No. 1, 2001.
8. **W.S. Wijesoma**, K.R.S. Kodagoda, *Synthesis of Stable Fuzzy PD/PID control laws for Robotic Manipulators from a Variable Structure Systems Standpoint*, Lecture Notes in Computer Science 1625, Springer, May 1999, pp 495-511.
9. **W. S. Wijesoma**, and R. J., Richards, "Robust Trajectory Following of Robots Using Computed Torque Structure With VSS", Int. J. Control, U.K.,1990, Vol. 52, No. 4.
10. **W. S. Wijesoma**, D. F. H. Wolfe, and R. J. Richards, "Eye-To-Hand Co-ordination with Reduced Reliance on Kinematic and Vision System Calibration for Vision Guided Robot Control Applications", Int. J of Robotics Research, USA, MIT Press, Feb., 1993, Vol. 12, No 1.

CURRENT RI PARTNERS AND PROJECTS

Guzman Javier Ibanez (Simtech), "Collaborative Autonomous Systems for Built Environments—CARSyB, SERC-A*STAR, (\$\$750,000.00).



XIE Lihua

PhD Newcastle (NSW)

Associate Professor

School of Electrical & Electronic Engineering /

Division of Control & Instrumentation

Nanyang Technological University

50 Nanyang Avenue, S2-B2a-14, Singapore 639798

Phone: 6790 4524

E-mail: elhxie@ntu.edu.sg

Lihua Xie received the B.E. and M.E. degrees in electrical engineering from Nanjing University of Science and Technology in 1983 and 1986, respectively, and the Ph.D. degree in electrical engineering from the University of Newcastle, Australia, in 1992. From April 1986 to January 1989, he was a teaching assistant and then a lecturer in the Department of Automatic Control, Nanjing University of Science and Technology. He joined the Nanyang Technological University, Singapore, in 1992 where he is currently an associate professor at the School of Electrical and Electronic Engineering. From November 1998 to July 1999, he was a visiting fellow in the Department of Electrical and Electronic Engineering, the University of Melbourne, Australia. He is a guest professor of Xiamen University and Nanjing University of Science and Technology and a visiting professor of Dalian University of Science and Technology of China. He has authored and coauthored one book and over 100 refereed journal articles. His research works have been well cited by control community with SCI of over 700. He is a senior member of IEEE and an associate editor, Conference Editorial Board, IEEE Control Systems Society.

MAJOR RESEARCH INTERESTS

Major research interests include system modelling, robust control, noise and vibration control, disk drive servo, estimation theory and digital signal processing.

RECENT REPRESENTATIVE PUBLICATIONS

1. S. Xie and L. Xie, "Decentralized stabilization of a class of interconnected stochastic nonlinear systems," IEEE Trans. Automatic Control, USA, Vol. 45, No. 1,2000, pp. 132-137.
2. S. Xie and L. Xie, "Stabilization of a class of uncertain large-scale stochastic systems with time delays," Automatica, UK, Vol. 36,2000, pp. 161-167.
3. H. Zhang, L. Xie and Y.C. Soh, " deconvolution filtering, prediction and smoothing: A Krein space polynomial systems approach," IEEE Trans. Signal Processing, USA, Vol. 48, No. 3,2000, pp. 888-892.
4. C. Du, L. Xie and Y.C. Soh, "H-infinity filtering of 2-D discrete time systems," IEEE Trans. Signal Processing, USA, Vol. 48, No. 6,2000, pp. 1760-1768.
5. L. Xie, S. Wang, C. Du and C. Zhang, "H-infinity deconvolution of periodic channels," Signal Processing, The Netherland, Vol. 80,2000, pp. 2365-2378.
6. C. Du, L. Xie and C. Zhang, " control and robust stabilization of two-dimensional systems in Roesser models," Automatica, UK, Vol. 37,2001, pp. 205-211.
7. L. Xie, E. Fridman and U. Shaked, "Robust H-infinity control of distributed delay systems with application to combustion control," IEEE Trans. Automatic Control, USA, Vol. 46, No. 12,2001, pp. 1930-1935.
8. U. Shaked, L. Xie and Y.C. Soh, "New approaches to robust minimum variance filter design," IEEE Trans. Signal Processing, USA, Vol. 49, No. 11,2001, pp. 2620-2629.
9. L. Xie, C. Du, Y.C. Soh and C. Zhang, "H-infinity and robust control of two-dimensional systems in Fornasini-Marchesini second model," Multi-dimensional Systems and Signal Processing, USA, Vol. 13, pp. 265-287, 2002.
10. H. Zhou, L. Xie and C. Zhang, "A direct approach to H2 optimal deconvolution of periodic channels," IEEE Transactions on Signal Processing, USA, Vol. 50, No. 7,2002, pp. 1685-1698.
11. L. Xie, C. Du, C. Zhang and Y.C. Soh, "H-infinity deconvolution filtering of 2-D digital systems," IEEE Transactions on Signal Processing, USA, Vol. 50, No. 9,2002, pp. 2319-2332.
12. C. Zhang and L. Xie, "Periodic stabilization of look ahead filters in VLSI implementation," IEEE Transactions on Automatic Control, Vol. 47, No. 8, pp. 1362-1266,2002.