

## CURRICULUM VITAE

Thomas J. Harris, P.Eng.  
Vice-Principal (Advancement) &  
Professor of Chemical Engineering  
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March 2011

## EDUCATION

Degree	University	Department	Year
Ph.D.	McMaster	Chemical Engineering	1980
M.Eng.	McMaster	Chemical Engineering	1977
B.Sc.	Queen's	Chemical Engineering	1975

## ACADEMIC AND PROFESSIONAL APPOINTMENTS INCLUDING ACADEMIC ADMINISTRATION

Dates	Rank and Position	Department	Institution
January 1, 2010	Vice-Principal (Advancement) & Professor		Queen's University
July 1, 1996	Dean & Professor	Faculty of Applied Science	Queen's University
Reappointed July 2001-July 2007			
July 1, 1992	Professor and Head of Chemical Engineering Department	Chemical Engineering	Queen's University
July 1, 1986	Associate Professor Queen's National Scholar	Chemical Engineering	Queen's University
April 1984	Senior Engineer	Engineering Services	E.I. Dupont de Nemours, Wilmington DE
July 1983	Technical Supervisor	Process Modelling & Control	Monsanto Chemical Co., Decatur, AL
July 1982	Engineering Specialist	Process Modelling & Control	Monsanto Chemical Co., Decatur, AL
January 1980	Senior Engineer	Process Modelling & Control	Monsanto Chemical Co., Decatur, AL

## **HONOURS: ACADEMIC, SCHOLARLY AND PROFESSIONAL**

2007 - Lifetime Member, Alma Mater Society, Queen's University  
2007 - Honorary President, Alma Mater Society, Queen's University  
2005 - T. Geoffrey Flynn Advancement Champion Award  
2005 - D.G. Fisher Award, Systems and Control Division, Canadian Society for Chemical Engineering  
2004 - Fellow, Canadian Academy of Engineering (FCAE)  
1998 - Fellow, Canadian Society for Chemical Engineering (FCIC)  
1992 - Best Paper Award, Canadian Journal of Chemical Engineering (co-author Mr. Lane Desborough)  
1992 - Awarded Golden Apple for Excellence in Teaching (in Applied Science)  
1986 - Appointed Queen's National Scholar

## **SIGNIFICANT UNIVERSITY ADMINISTRATIVE DUTIES**

2010- Vice-Principal (Advancement) Queen's University  
1996-2007 - Dean, Faculty of Applied Science, appointed July 1, 1996 & Reappointed July 2001  
1996-2007 - Ex Officio Member of Queen's University Senate  
1996-2007 - Member Advisory Research Council  
2005 - Member, Principal's Advisory Task Force on Community Relations  
2001-2002 - Member, Principal's Advisory Committee on Budget  
2000-2004 - Chief Negotiator, Queen's University  
1995 - Senate Subcommittee on Endowment Policy for Chairs  
1993 - Principal's Committee on Operating Efficiency  
1992-1996 - Department Head, Chemical Engineering  
  
2007-2009 - Chair, Human Mobility Research Centre (HMRC)  
1999-2007 - Member, Advisory Board MBA (residential program), Queen's School of Business  
1999-2007 - Director, Human Mobility Research Centre (HMRC)  
1999-2005 - Director, Centre for Automotive Materials & Manufacturing (CAMM)  
2002-2005 - Director, Centre for Water and the Environment (CWE)  
2002-2004 - Director, Centre for Advanced Manufacturing of Ceramics and Nanomaterials  
2004-2007 - Director, Queen's / RMC Fuel Cell Research Centre

## **NON-UNIVERSITY COMMITTEES**

2009-2012 - Member of the Ontario Research Fund Advisory Board (ORFAB)  
2006-2011 - Director, Management Board, Ontario Centres of Excellence in Energy  
1999-2005 - Director, Materials and Manufacturing Ontario (MMO)  
2004-2006 - Chair, University Network on Excellence in Nuclear Engineering (UNENE)  
2002-2008 - Director, University Network on Excellence in Nuclear Engineering (UNENE)  
2004-2005 - Chair, Council of Ontario Deans of Engineering (CODE)  
2003-2004 - Vice Chair, Council of Ontario Deans of Engineering (CODE)  
2001-2004 - Director, Advanced Materials and Manufacturing Institute (ADMI)  
1999-2000 - Chair, Council of Ontario Deans of Engineering (CODE)  
1996-2003 - Chair, Publication Committee, Canadian Journal of Chemical Engineering  
1992-1994 - NSERC Operating Grant Committee for Chemical Engineering & Metallurgy (GSC -04)  
1990-1991 - Founding Chair, Systems and Control Division, Canadian Society for Chemical Engineering  
1989-1990 - Chair, Kingston Chapter, Canadian Society for Chemical Engineering

## SCHOLARLY AND PROFESSIONAL ACTIVITIES

**ARTICLES IN REFEREED JOURNALS** \* denotes corresponding author, bold is graduate student or undergraduate student

48. **Wu, S., McLean, K.**, Harris, T.J., and K.B. McAuley\*, (2011), *Selection of Optimal Parameter Set Using Estimability Analysis and MSE-based Model-Selection Criterion*, *International Journal of Advanced Mechatronic Systems* (accepted April 11, 2011)
46. Harris, T.J. and **Wei-Yu**, (2011), *Variance decompositions of nonlinear time series using stochastic simulation and sensitivity analysis*, *Statistics and Computing* (in press)
47. **Wu, S.**, McAuley, K.B. and T.J. Harris (2011), *Selection of Simplified Models: II. Development of a Model Selection Criterion Based on Mean-Squared Error*, *Can. J. Chem. Eng.* **89**, pp. 325-336
45. **Wu, S.**, McAuley, K.B. and T.J. Harris\* (2011), *Selection of Simplified Models: I. Analysis of Model Selection Criteria using Mean-Squared Error*, *Can. J. Chem. Eng.* **89**, pp. 148-158
44. Harris, T.J.\* and **Yuan, H.**, (2010), *Filtering and frequency interpretations of Singular Spectrum Analysis*, *Physica D: Nonlinear Phenomena* **239**, pp.1958-1967
43. Harris, T.J.\* and **Wei-Yu** (2010), *Variance Decomposition of Nonlinear Dynamic Stochastic Systems*, *Journal of Process Control* **20**, pp. 195-205.
42. Harris, T.J.\* and **Wei-Yu** (2009), *Parameter Uncertainty Effects on Variance-based Sensitivity Analysis*, *Reliability Engineering and System Safety*, **94**, 596-603
41. Harris, T.J.\*, *Interpretations of Multivariate Performance Indices (2009)*, *Journal of Process Control*, **19**, pp 701-710
40. **Wu, S.**, Harris, T.J.\* and K.B. McAuley (2007), *The Use of Simplified or Misspecified Models*, *Canadian Journal of Chemical Engineering* **54**, pp. 386-398.
39. Harris, T.J.\* and **Wei-Yu** (2007), *Controller Assessment for a Class of Nonlinear Systems*, *Journal of Process Control* **17**, pp. 607-619
38. **Quinn, S.L.**, Harris,T.J.\* and D.W. Bacon (2005), *Measuring Uncertainty in Control-Relevant Statistics*, *Journal of Process Control*, **15**, pp. 675-690
37. Harris, T.J.\* (2004), *Statistical Properties of Quadratic-Type Performance Indices*, *Journal of Process Control*, **14**, 899-914
36. **Wei-Yu** and T.J. Harris\* (2003), *Analysis of Multivariable Controllers Using Markov Chains*, *International Journal of Adaptive Control and Signal Processing*, **17**, 569-588
35. **Seppala, C.T.**, Harris, T.J\*., and D.W. Bacon (2002), *Time Series Methods for Dynamic Analysis of Multiple Controlled Variables*, *Journal of Process Control*, **12**, pp 257-276
34. **Quinn, S.L.**, Bacon, D.W., and T.J. Harris\* (2000), *Notes on Likelihood Intervals and Profiling*, *Communications in Statistics* **29**, pp. 108-130

33. **Quinn, S.L.**, Bacon, D.W., and T.J. Harris\* (1999), *Using Generalized Profiling to Estimate Likelihood Intervals for Model Predictions and Other Functions of Model Parameters*, Canadian Journal of Chemical Engineering, **77**, pp 723-737.
32. Harris, T.J.\*, **Seppala, C.T.**, and L.D. Desborough (1999), *A Review of Performance Monitoring and Assessment Techniques for Univariate and Multivariate Control Systems*, Journal of Process Control, **9**, pp 1-17
31. Harris, T.J.\*, **Wilkinson, R.**, and J. Davis (1998), *Numerical Inversion of Characteristic Equations with Applications to Quadratic Forms in Normal Variables*, Communications in Statistics: Simulation and Computation, **27**, pp 215-228
30. Harris, T.J.\*, **Seppala, C.T.**, **Jofriet, P.J.**, and B.W. Surgenor (1996), *Plant-Wide Feedback Control Performance Assessment Using an Expert-system Framework*, Control Eng. Practice, **4**, pp. 1297-1303
29. **Jofriet, P.**, **Seppala, C.**, Surgenor, B. and T. J. Harris\* (1996), *An Expert system For Control Loop Performance*, Pulp & Paper Canada, **97** , pp. 207-211
28. Harris, T.J.\*, **Boudreau, T.**, and J.F. MacGregor (1996), *Performance Assessment of Multivariable Feedback Controllers*, Automatica, **32**, pp. 1505-1518
27. **Piette, R.**, Harris, T.J., and P.J. McLellan\* (1995), *Graphical Interpretation of Steady State Interaction Measures*, Industrial & Engineering Chemistry Research, **34**, pp. 4436-4450
26. Amphlett, J.C.\*, **Baumert, R.M.**, Mann, R.F., **Peppley, B.A.**, Roberge, P.R., and T.J. Harris (1995), *Performance Modeling of the Ballard Mark IV Solid Polymer Electrolyte Fuel Cell, I. Mechanistic Model Development*, J. Electroch. Soc., **142**, pp. 1-8
25. Amphlett, J.C.\*, **Baumert, R.M.**, Mann, R.F., **Peppley, B.A.**, Roberge, P.R., and T.J. Harris (1995), *Performance Modeling of the Ballard Mark IV Solid Polymer Electrolyte Fuel Cell, II. Empirical Model Development*, J. Electroch. Soc., **142**, pp. 9-15
24. **Yuet, P.K.**, Harris, T.J., and M.F.A. Goosen\* (1995), *Mathematical Modelling of Immobilized Animal Cell Growth*, Biomaterials, Artificial Cells, and Immobilization Biotechnology, **23**, pp. 109-133
23. **Shirt, R.W.**, Harris, T.J.\*, and D.W. Bacon (1994), *Experimental Design Considerations for Dynamic Considerations*, Ind. Eng. Chem. Res. **33**, pp. 2656-2667
22. **Desborough, L.D.**, and T.J. Harris\* (1994), *Control Performance Assessment*, Pulp & Paper Canada **94:11**, pp. 441-443
23. McAuley, K.B., **Talbot, J.P.**, and T.J. Harris\*, (1994), *A Comparison of Two-Phase and Well-Mixed Models for Fluidized-Bed Polyethylene Reactors*, Chem. Eng. Sci. **49**, pp. 2035-2045.
20. **Desborough, L.D.** and T.J. Harris\* (1993), *Performance Assessment Measures for Univariate Feedforward/Feedback Control*, Canadian Journal of Chemical Engineering, **71**, 605-616
19. **Berg, D.** and T.J. Harris\* (1993), *Characterization of Multicomponent Diffusion Effects in MTBE Synthesis*, I&EC Research, **32**, 2147-2158
18. Harris, T.J., and J.F. MacGregor\* (1993), *The Exponentially Weighted Moving Variance*, Journal of Quality Technology, **25** 106-118
17. **Desborough, L.** and T.J. Harris\* (1992), *Normalized Performance Measures for Feedback Controllers*, Canadian Journal of Chemical Engineering, **70**, pp. 1186-1197

16. Harris, T.J.\* and J.H. Davis (1992), *An Iterative Method for Matrix Spectral Factorization*, SIAM Journal of Statistical and Scientific Computing, **13**, pp. 531-540
15. Harris, T.J.\* (1992), *One Step Optimal Controllers for Nonsymmetric and Nonquadratic Cost Functions*, Technometrics, **34**, pp. 298-306
14. **Foley, M.** and T.J. Harris\* (1992), *Performance and Structure of  $H_2$  Controllers*, Journal of Optimal Control: Applications & Methods, **13**, pp. 1-28
13. Harris, T.J.\* and W.H. Ross (1991), *Statistical Process Control Procedures for Correlated Observations*, Canadian Journal of Chemical Engineering, **69**, pp. 48-57
12. **Kwok, W.Y.**, Kiparissides, C., **Yuet, P.**, Harris, T.J. and M.F.A. Goosen\* (1991), *Mathematical Modelling of Protein Diffusion in Microcapsules: A Comparison with Experimental Results*, Canadian Journal of Chemical Engineering, **69**, pp. 361-372
11. **McLellan, P.J.**, Harris, T.J.\* and D.W. Bacon (1990), *Error Trajectory Descriptions of Nonlinear Controller Designs*, Chemical Engineering Science, **45**, 3017-3034
10. Harris, T.J.\* and **P.J. McLellan** (1990), *GMC: A Case Study Revisited*, Canadian Journal of Chemical Engineering, **68**, 1066-1070
9. MacGregor, J.F. and T.J. Harris (1990), *Discussant*, Technometrics, **32**, 23-26
8. Harris, T.J.\* (1989), *Assessment of Control Loop Performance*, Canadian Journal of Chemical Engineering, **67**, 856-861
7. **Kozub, D.**, MacGregor, J.F.\* and T.J. Harris (1989), *Optimal IMC Inverses: Design and Robustness Considerations*, Chemical Engineering Science, **44**, 2121-2136
6. Harris, T.J.\*, MacGregor, J.F., (1987), *Design of Multivariable Linear Quadratic Controllers Using Transfer Functions*, AIChE Journal, **33**, 1481-1497
5. Harris, T.J.\*, and B. Tyreus, (1987), *Comments on 'Internal Model Control 4: PID Controller Design Using Transfer Functions'*, Industrial and Engineering Chemistry, **26**, 2161-2162.
4. MacGregor\*, J.F., Harris, T.J., and J.D. Wright, (1984), *Duality Between the Control of Processes Subject to Randomly Occurring Deterministic Disturbances and ARIMA Stochastic Disturbances*, Technometrics, **26**, 389-397.
3. MacGregor, J.F\*, Harris, T.J., and J.D. Wright, (1982), *An Overview of Discrete Stochastic Controllers: Generalized PID Algorithms with Dead-Time Compensation*, Canadian Journal of Chemical Engineering, **60**, 425-432.
2. MacGregor, J.F\*, Harris, T.J., and J.D. Wright, (1980), *Self-Tuning and Adaptive Controllers: An Application of Catalytic Reactor Control*, Technometrics, **22**, 153-164
1. MacGregor, J.F.\*, Harris, T.J., and J.D. Wright, (1980), *Optimal Sensor Location with an Application to a Packed Bed Tubular Reactor*, AIChE J., **26**, 910

## Submitted or In Review:

Liba, M.J., Harris, T.J.\*, Kang, K., and M. Guay (2011), *Optimal sensor location for stochastic linear systems using model predictive control*, submitted to Journal of Process Control (March)

## CHAPTERS IN BOOKS

3. Harris, T.J. and Seppala, C.T., (2002), *Recent Developments in Controller Performance Monitoring and Assessment Techniques*, in Chemical Process Control-VI: Assessment and New Directions for Research, AIChE Symposium Series # 326: Vol 98. Editors, J.B. Rawlings, B.A. Ogunnaike and J.W. Eaton, pp208-222.

2. Harris, T.J., (1994), *The Implications of Quality Programs on Chemical Engineering Control & Design*, in Foundations of Computer Aided Process Operations, Elsevier (a conference held every 5 years) 25 pages

1. Yuet, P.K., Kwok, W., Harris, T.J., and Goosen, M.F.A. (1993), *Mathematical Modelling of Protein Diffusion and Cell Growth in Microcapsules*, Chapter 5 in: Fundamentals of Animal Cell Encapsulation and Immobilization, M.F.A. Goosen (Ed.), CRC Press, Boca Raton, 79-112

## PATENTS

*Liquid Phase Preparation of (meth)-Acrylate from Alpha-olefin*, U.S. Patent 5,670,702. Issued 23 September 1997.

## PAPERS IN CONFERENCE PROCEEDING

*Dynamic Analysis of Variance Methods for Multivariate Control System Data*, 1<sup>st</sup> International Symposium on Industrial Statistics (Understanding Variation: A Key to Successful Quality Improvement), Linköping, Sweden, August 19-21, 1999

## PAPERS IN REFEREED CONFERENCE PROCEEDING

4. Wei-Yu\*, Wilson, D., Young, B. and Harris, T.J., *Variance Decompositions of Nonlinear Systems*, 7th IEEE International Conference on Control & Automation, Christchurch, New Zealand, December, 2009 (Accepted)

3. Harris, T.J. and **C.T. Seppala**, (2001), *Recent Developments in Controller Performance Monitoring and Assessment Techniques*, Chemical Process Control VI, January 2001, Tuscon, Arizona

2. Desborough, L.D. and T.J. Harris (1992), *Control Performance Assessment*, The Dream versus Reality; Pulp and Paper Conference, Whistler, B.C., 69-74

1. Harris, T.J. (1993), *Towards a Paradigm for Process Control - An Overview of the Problems and Issues*, American Statistical Association, Proceedings of the Section on Quality and Productivity, 15-24

## TECHNICAL REPORTS

2. Jofriet, P., Seppala, C.T. Surgenor, B.W., Harris, T.J., and M. Harvey, *An Expert System for Control Loop Performance Analysis*, Final Report for NSERC CRD project, (2 /95) 54 pages

1. Jackson, B.W. and T.J. Harris, (1994), *Catalytic Distillation Summary*: Research Report NOVA Petrochemicals (6/94) 48 pages

## Many confidential reports with Monsanto Chemical Company & E.I. Dupont de Nemours

### ABSTRACTS and/or PAPERS read

Wu, S., K.B. McAuley and T.J. Harris, "Ranking Parameter Estimability Using Mean Squared Error", 8<sup>th</sup> World Conference on Chemical Engineering, Montreal, August 23-27<sup>th</sup>, 2009

Wu, S., K.B. McAuley and T.J. Harris, "An Analysis of Model Selection Criteria in the Case of Underfitting", poster presented at the Second Canada-France Congress, Montreal, June, 2008.

Harris, T. J., K. B. McAuley and S. Wu, *Not so Simple! The Statistical Analysis of Simplified and Misspecified Models*, 58<sup>th</sup> Canadian Chemical Engineering Conference, Edmonton, Oct. 2007. **Invited Talk.**

Wu, S., Harris, T.J., and K.B. McAuley, *The Use of Simplified Modes in Linear Case*, CMS-MITACS Joint Conference, Winnipeg, MB, June 2007, Paper 58.

A. Soon, T.J. Harris and P.J. McLellan, *A Generalized Profiling Approach to Inference Analysis in System Identification*, Canadian Chem. Eng. Conf., Sherbrooke, October 2006.

Wu, S., Harris, T.J., and K.B. McAuley, *When Simplified Models are Better than the True Model*, 55<sup>th</sup> Canadian Chemical Engineering Conference, Toronto (2005), Paper 487

Wei Yu, and T.J. Harris, *Parameter Uncertainty Effects on Input Sensitivity Analysis*, 54<sup>th</sup> Canadian Society for Chemical Engineering Conference, Paper #250, Calgary (2004)

Harris, T.J., and Wei-Yu, *Assessing Parameter Uncertainty Using Markov Chain Monte Carlo Methods*, 53<sup>rd</sup> Canadian Chemical Engineering Conference, Hamilton Ontario, Paper 273, October 28-30 (2003)

Uche, I., and T.J. Harris, *Quantifying Model Uncertainty Using Model Error Modelling*, 52<sup>nd</sup> Canadian Chemical Engineering Conference, Vancouver (2002),

Wei-Yu, and T.J. Harris, *Analysis of Multivariable Controllers Using Markov Chains*, 52<sup>nd</sup> Canadian Chemical Engineering Conference, Vancouver (2002)

Liew, S.C.N., and T.J. Harris, *Estimation of Cointegrated Relationships in Process Data*, 50<sup>th</sup> Canadian Chemical Engineering Conference, Montreal (2000)

Seppala, C.T., Harris, T.J., and D.W. Bacon, *Introduction to the Role of Cointegration In the Analysis of Control System Data*, Session #71, 49<sup>th</sup> Canadian Chemical Engineering Conference, Saskatoon (1999)

Miller, N., McLellan, P.J., and T.J. Harris, *Performance Assessment Using Nonlinear Time Series Models*, Session #64, 48<sup>th</sup> Canadian Chemical Engineering Conference, London, Ontario, (1998)

Quinn, S.L., Bacon, D.W., and T.J. Harris, *How Big is N for Time Series Models*, Session #64, 48<sup>th</sup> Canadian Chemical Engineering Conference, London, Ontario, (1998)

Boudreau, F., MacGregor, F.J., and T.J. Harris, *Relation Between Delay Structure and Performance of Multivariable Minimum Variance Controllers*, AIChE Winter Meeting, Chicago, IL Paper 149b (1996)

T.J. Harris, F. Boudreau and J.F. MacGregor, *Performance Assessment of Multivariable Feedback Controllers*, #28, 45<sup>th</sup> Canadian Chemical Engineering Conference, Quebec City (1995)

T.J. Harris, *Input Signal Design for Identification*, 43rd Canadian Chemical Engineering Conference, Ottawa, Ontario (1993)

Berg, D. and T.J. Harris, *Effect of Mass Transport Resistances of the Synthesis of MTBE in Catalytic Distillation Environment*, 42nd Canadian Chemical Engineering Conference, Toronto, Ontario (1992)

Desborough, L.D. and T.J. Harris, *Extension to Statistical Methods for Control Loop Assessment*, ACC, Chicago, Illinois (1992)

Amphlett, J.C., Harris, T.J., Mann, R.F., Peppley, B.A. and P.R. Roberge, *Computer Simulation of a Catalytic Methanol Reforming Hydrogen Generator for a Portable Fuel Cell Power Plant*, 41st Canadian Chemical Engineering Conference, Vancouver, B.C., October (1991)

Foley, M. and T.J. Harris, *Performance and Structure of  $H_{\infty}$  Controllers*, 41st Canadian Chemical Engineering Conference, Vancouver, BC, October (1991)

Fogal, D. and T.J. Harris, *Detection of Nonlinearities in Process Operation Data*, 41st Canadian Chemical Engineering Conference, Vancouver, BC, October (1991)

McLellan, P.J., Harris, T.J. and D.W. Bacon, *Disturbance Decoupling of Staged Chemical Processes*, ACC, San Diego, CA (1990)

Harris, T.J. and P.J. McLellan, *Deadtime and Disturbance Induced Performance Limitations in Multivariable Control*, 40th Canadian Chemical Engineering Conference, Halifax, NS, July (1990)

McLellan, J.P., Harris, T.J. and D.W. Bacon, *The Nonlinear Inversion Problem in Process Control*, 39th Canadian Chemical Engineering Conference, Hamilton, Ontario (1989)

Harris, T.J., *One Step Optimal Controllers for Nonsymmetric and Nonquadratic Cost Functions*, 39th Canadian Chemical Engineering Conference, Hamilton, Ontario (1989)

Koung, C.W. and T.J. Harris, *Sensitivity of the Relative Gain Array*, 39th Canadian Chemical Engineering Conference, Hamilton, Ontario (1989)

Shirt, R.W., Harris, T.J. and D.W. Bacon, *Selection of Perturbation Signals for Identification of Dynamic Behavior*, 39th Canadian Chemical Engineering Conference, Hamilton, Ontario (1989)

Yuet, P.K., Harris, T.J. and M.F.A. Goosen, *Mathematical Modelling of Animal Cell Growth in Microcapsules*, 39th Canadian Chemical Engineering Conference, Hamilton, Ontario (1989)

Jackson, B.W. and T.J. Harris, *Creative and Innovative Problem Solving Using Flowsheet Simulators*, 39th Canadian Chemical Engineering Conference, Hamilton, Ontario (1989)

## POPULAR ARTICLES

Jackson, B.W. and T.J. Harris, *Creative and Innovative Problem Solving Using Flowsheet Simulators*, Canadian Chemical News, pp. 19-21 (June 1990)

## INVITED SPEAKER:

*An Analysis of Model Selection Criteria (MSC) in the Case of Underfitting (with S. Wu & K.B. McAuley), MITACS 2009, Fredericton NB, June 2009*

*Inference in Nonlinear Regression: Progress and Challenges, Dept of Statistics, University of Toronto, January, 2008.*

*Not So Simple! Analyzing Simplified & Misspecified Models, 57th Canadian Chemical Engineering Conference, Edmonton, Alberta, 2007. Keynote Presentation*

*Interpretations and Analysis of Performance Bounds for Multivariable Systems, 55th Canadian Chemical Engineering Conference, Toronto Canada, October 16-19th 2005, Paper 297. D.G. Fisher Award Lecture*

*Observations & Thoughts on Controller Assessment & Performance Monitoring, EXXonMobil ACAP/RTO Meeting, May 2, 2005, Toronto*

*Observations & Thoughts on Controller Assessment & Performance Monitoring, Control Systems 2004, Quebec City (2004)*

*Recent Developments in Controller Performance Monitoring and Assessment Techniques, Chemical Process Control VI, January 2001, Tuscon, Arizona (with C.T. Seppala)*

*Dynamic Analysis of Variance Methods for Multivariate Control System Data, 1<sup>st</sup> International Symposium on Industrial Statistics (Understanding Variation: A Key to Successful Quality Improvement), Linköping, Sweden, August 19-21, 1999*

*Current Status & Research Needs in Process Control Diagnostics, McMaster University Advanced Process Control Consortium, Hamilton, ON, Spring 1998*

*A Review of Performance Monitoring and Assessment Techniques for Univariate and Multivariate Control Systems, ADCHEM '97, Banff, Alberta*

*Harris, T.J., Performance Assessment And Process Monitoring Techniques For Univariate Control Systems, AspenWorld Conference, Boston, MA, October 1997*

*Statistical Methods for Analysis of Engineering Control Systems, First Spring Research Conference on Statistics in Industry & Technology, Greensborough, North Carolina, June 1994*

*Statistical Methods for Analysis of Process Control Systems, American Society for Quality Control (ASQC) Fall Technical Conference, Rochester, N.Y., October 1993*

*Quality Issues in Process Design and Process Operations, Foundations of Computer Aided Operations (FOCAPO), (A conference sponsored by AIChE held every 5 years), Gunneston, CO, July 1993*

*Process Monitoring - Discussant Gordon Research Conference on Statistics in Chemistry and Chemical Engineering, August 1993*

*Towards a Paradigm for Process Control: An Overview of the Problems and Issues, American Statistical Association, Boston, MA, August 1992*

*Multivariable Control Applied to Photographic Film Production - Discussant, Gordon Research Conference, August 1990*

*Interface 90 - Interfaces between Computing Science and Statistics, On-line Statistics for Process Control*

*Analysis*, East Lansing, Michigan, May 1990

*Discussant*, Gordon Research Conference on Statistics in Chemistry and Chemical Engineering, New Hampton, NH, August 1990

## THESIS SUPERVISED

29. Shaohua Wu, *Model Error Modelling Methods in Chemical Engineering*, (co-supervised with K.B. McAuley), Ph.D. (2009)
28. Wei Yu, *Variance Analysis for Nonlinear Systems*, P.h.D. (2007)
27. Wong, John, *Fault Detection Application of Alternative Mean-Centering and Pattern Matching Techniques in Non-Repeated Multivariate Time-Series Data Trajectories* (co-supervised with P.J. McLellan), M.Sc. (2006)
26. Wu,S., *Two-Step Estimation in Linear Regression* (co-supervised with K.B. McAuley), M.Sc. (2005).
25. Soon, A., *A Generalized Profiling Approach to Inference Analysis in System Identification* (co-supervised with P.J. McLellan), M.Sc. (2005)
24. Breck, C., *Fault Detection for an Aircraft Environment Control system using Dynamic Principal Component Analysis*, (co-supervised with P.J. McLellan), M.Sc. (2005)
23. Uche, Ikenna, *An Analysis of Model Error Modelling*, M.Sc (2003)
22. Wei-Yu, *Applications of Time Series Count Data for Process Analysis*, M.Sc. (2002)
21. Liew, Chen Nei, *Estimation of Cointegrating Relationships in Process Data*, M.Sc. (2002)
20. Patton, M., *Describing Uncertainty in State Estimates* (co-supervised with P.J. McLellan), M.Sc. (2000)
19. Seppala, C.T., *Dynamic Analysis of Variance Methods for Monitoring Control System Performance*, (co-supervised with D.W. Bacon), Ph.D. (1999)
18. Quinn, S.L., *Measuring and Predicting Uncertainty in Control-Relevant Statistics*, (co-supervised with D.W. Bacon), Ph.D. (1999)
17. Laflamme, J., *Dynamic model of the solid state polymerization of nylon 6,6*, (co-supervised with P.J. McLellan), M.Sc (1997)
16. Neagu, L. *Production of BHP by Catalytic Distillation*, (co-supervised with B.W. Jackson), M.Sc. (1997)
15. Logan., G.A., *Synthesis of dimethyl carbonate with CuC12*, (co-supervised with B.W. Jackson), M.Sc. (1997)
14. Zagobelny, J., *System Identification Techniques for a Rolling Mill Gauge System*, (co-supervised with M. Bayoumi), M.Sc. (1996)
13. Rose, J., *Reactive Distillation*, (co-supervised with B. Jackson), M.Sc. (1994)
12. Piette, R., *Geometric Interpretation of Interaction Measures*, (co-supervised with P.J. McLellan), M.Sc. (1994)
11. Berg, David, *Mass Transfer Resistances in MTBE Synthesis*, Ph.D. (1994)

10. Baumert, R.M., *Performance Modelling of the Ballard Mark IV Solid Polymer Electrolyte Fuel Cell*, (co-supervised with R.F. Mann, RMC), M.Sc. (1993)
9. Foley, Michael, *H-infinity Methods for Chemical Process Control*, Ph.D. (1993)
8. Peppley, B., *Catalytic Steam Reforming of Methanol Using a Commercial Low Temperature Shift Catalyst*, (co-supervised with R.F. Mann, RMC), M.Sc (1993)
7. Kuye, M.A., *An Evaluation of Microbial Biomass Estimation Techniques in Dynamic Fermentation Processes and Their Impact on Modelling*, (co-supervised with A.J. Daugulis), M.Sc.(1992)
6. Desborough, L., *Performance Assessment Measures for Univariate Control*, M.Sc. (1992)
5. McLellan, P.J., *Nonlinear Error Trajectory Controllers for Output Tracking and Disturbance Rejection*, (co-supervised with D.W. Bacon), Ph.D. (1990)
4. Yuet, P.K., *Mathematical Modelling of Animal Cell Growth in Micocapsules*, (co-supervised with M.F.A. Goosen), M.Sc. (1990)

## TITLES OF ALL GRADUATE THESES IN PROGRESS

Dharmesh Goradia, *Statistical Uncertainty Analysis for Controller Design and Analysis*, M.Sc. (part time)

Hui Yuan, *Use of MTM and SSA for Process Analysis*, Ph.D.

Bahareh Golfar, *The application of Higher Order Statistics for Analysis of Compartmental Models* (co-supervised with P.J. McLellan), Ph.D.

Michael Liba, *Applications of Uncertainty Analysis to the Control of Distributed Energy Systems* (co-supervised with M. Guay) M.Sc.

## EVIDENCE OF RESEARCH IMPACT

My research focuses on the application and development of applied statistics in chemical engineering. My research draws upon developments in applied statistics, econometrics and chemical engineering. My research program can be generally divided into two areas.

**Performance Monitoring & Controller Performance Assessment:** The body of material related to controller performance monitoring and assessment represents my most significant contribution to both research and practical applications. The funding by provided by NSERC over 20 years has been crucial to my contributions to this area. The originating paper on this topic was my sole-authorship paper published in 1989 (203 citations). This was the first paper to propose the use of minimum variance control as a benchmark against which the performance of other controllers can be compared, and to demonstrate that the minimum variance benchmark could be obtained directly from the prediction error of the disturbance over the process time delay horizon. In addition, the paper noted that the prediction error over the time-delay horizon is a feedback-invariant characteristic of processes, i.e., it doesn't

change if the controller is changed. Subsequent material published with Lane Desborough, an MSc. Student, in 1992 and 1993, laid the groundwork for development of theoretical and practical applications and extensions in academia and industry. A number of important new developments related to exogenous variables, such as setpoints and disturbances (both stochastic and deterministic) were presented in a unifying and fundamental fashion in Harris et al. (1999), together with a comprehensive review of the controller performance monitoring literature. These developments enable setpoints and disturbances to be treated as instances of exogenous variables using a common framework, and that the general methodology is capable of treating these types of disturbances in a straightforward fashion. In addition, it was shown that a number of other performance indices, such as settling time, could be readily extracted from the model that is used to estimate performance indices.

Our proposed methodology for controller performance monitoring and assessment has seen widespread application in oil and gas processing, pulp and paper manufacturing, iron and steel production, food processing, cement production and fibers processing. In addition, this methodology and extensions have provided the basis for an active engineering services industry. Company's now selling software directly based on this material and extensions include: Control Arts (California), Matrikon (Edmonton) and Honeywell Hi-Spec Solutions (California). Shell Development (Houston) has a control loop assessment package for the Shell Group of companies (US/Canada). E.I. DuPont de Nemours (Wilmington, DE) and Eastman Co. (Tennessee) also have implemented performance monitoring packages. Nearly every one of these packages incorporates some form of minimum variance benchmarking. The Honeywell Package was developed by Mr. Desborough, and Dr. Seppala (former Ph.D student) made significant contributions to the Shell product. Dr. Shannon Quinn (former Ph.D. student) led the development of Dofasco's technical group in statistical methods for performance improvement.

Our original research has also spawned considerable academic interest in controller performance assessment. Significant research efforts are underway / completed at the University of Alberta (Shah, Huang), University of Southern California (Qin), University of Texas (Edgar), UBC (Dumont), Illinois Institute of Technology (Cinar), Strathclyde (Grimble), and Imperial College (Thornhill), that is aimed at extending the basic methodologies to: i) unit operation-specific performance indices, ii) cascade systems, iii) multirate systems, iv) analysis of cycling and valve stiction (Shah & Thornhill), iv) alternate computational schemes, v) methods for estimating the time-delay structure required to calculate the performance bounds (Shah and Huang), vi) development of alternative interactor matrices to establish performance bounds in multivariate systems (Qin), vii) directionally dependent performance bounds for multivariable systems (Qin), viii) spectral interpretations, and ix) performance indices for PI and PID control.

Two key papers with Lane Desborough published in 1992 have been cited a total of 195 times, while the material with MacGregor and Boudreau, published in 1996, on multivariate performance monitoring has been cited 86 times and the more recent work with Seppala and Bacon (1999) been cited 98 times. Overall this body has work in performance monitoring and assessment has generated ~ 600 citations.

**Statistical Methodologies for Chemical Process Modeling:** Mathematical models form the basis for process development and improvement, and typically contain unknown parameters that must be estimated from data. These models may be used for control, analysis, and discrimination among competing mechanisms. Since the pioneering publication of Bates and Watts in 1981, it is generally well known in the statistics literature that confidence regions for parameters and functions of parameters (such as predictions) are poorly approximated by traditional linearization-based methods. Bates and Watts proposed profiling in 1981 as a technique for understanding the extent of uncertainty in parameter estimates, particularly in models in which the parameters appear nonlinearly. Application and extension of these methods has been an important focus on my research in the past two grant cycles. Applications to dynamical systems are discussed in Quinn et al. (2005). For example, profiling can be used to understand the impact of parameter uncertainty on the controller performance measures discussed above. These results represent contributions to both chemical engineering practice and statistical methodology, and have been published in both the chemical engineering and statistics literature. Current research is focused on examining the relationship between profiling and the confidence region / interval construction arising from the use of higher-order asymptotics developed by Fraser, Reid and co-workers. An extension of the higher-order asymptotic methods to multi-response estimation is being considered. The development and analysis of efficient numerical methods and the relationship between proposed constrained optimization approaches and homotopy methods is also being studied.

**Contributions to the Training of Highly Qualified Personnel** Most of my graduate students have gone on to work in industry both in the United States and Canada. Several have academic positions in Canadian universities. The area of process control is very interdisciplinary – requiring knowledge of chemical engineering, process control and a strong emphasis on statistics. I feel that graduates have been particularly well prepared. Many of them are providing leadership in applying process control techniques within their respective companies.

#### **Short Courses: 1988 – 1996**

**SPC Interfaces:** A 2 1/2 day industrial short course, which explores the interface between statistical process control and engineering process, control. Given with J. Stuart Hunter, Professor Emeritus, Princeton University, and Prof. J.F. MacGregor, McMaster University. As of July 1996, this course was offered 41 times in Canada, the United States, Asia, Europe and Australia. This course provides a forum for technology exchange with industry.

**Process Control Interfaces:** A one-day short course given for the American Statistical Association, 33rd Annual Technical Conference, Statistics and Quality: Keys to Competing in a Global Economy, Houston, Texas, October 25, 1989. This course has also been given for DuPont Canada Ltd. (2), Kodak (3), E.I. Dupont de Nemours & Co. (1) and Monsanto Co.