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Status Quo

Presently I am Newton International post doctoral fellow at School of Engineering, Swansea University, Swansea. My present research involves developing analytical tools and control commands for smart structures with uncertainty.

Research Interests

Smart Structures, Nonlinear and Intelligent control, Structural System Identification, Control of PDEs, Biomedical applications, Soft Computing, Earthquake Engineering.

Academic Positions

Newton International Fellow: Jan 2010 – Dec 2011
School of Engineering, Swansea University, Swansea, Wales, UK
Project: *Dynamics and control of smart structures with uncertainty*
Supervisor: Prof. Sondipon Adhikari

Post Doctoral Fellow: Mar 2009 – Dec 2010
Automatic Control Laboratory, IUT-Longwy, CRAN-CNRs, Université Henri Poincaré, Nancy, France
Project: *Modeling and observer design for thermoforming of glass in heat furnace*
Supervisor: Prof. Mohamed Boutayeb

Centenary Research Associate: Aug 2008 – Mar 2009
Aerospace Engineering Department, Indian Institute of Science, Bangalore, India
Project: *Analysis and control development for medical device for diabetic patients*
Supervisor: Dr. Radhakant Padhi

Educational Qualification

Ph.D. Civil Engineering: 2003 – 2008 (July 2008)
Indian Institute of Science, Bangalore, India
Thesis title: *Semi-active Control of Earthquake Induced Vibrations in Structures using MR Dampers: Algorithm Development, Experimental Verification and Benchmark Applications*
Supervisor: Prof. Ananth Ramaswamy
CGPA: 7.5/8.0

B.E. Civil Engineering: (First Class Honours) August 1999 – 2003
Jadavpur University, West Bengal, India
Special topics: *Computer methods in Engineering*, *Bridge Engineering*
Marks: 78%

Higher Secondary: (First Division) August 1997 – 1999
West Bengal Council of Higher Secondary Education, West Bengal, India.
Subjects: Physics, Chemistry, Mathematics, English and Bengali.
Specialization: Biology.
Marks: 81.00%

Secondary School Examination: (First Division) August−1997
West Bengal Board of Secondary Examination, West Bengal, India
Stream: General.
Specialization: Mathematics.
Marks: 84.38%

Research Experience

Title: *Dynamics and control of smart structural systems with uncertainty*

Supervisor: Prof. Sondipon Adhikari
School of Engineering, Swansea University, Swansea, Wales, UK

Description: The behavior of structural systems is inherently random due to the uncertainties in the system parameters and the environment. Such uncertainties include both parametric and nonparametric uncertainties. This research includes both parametric and nonparametric uncertainties while analyzing a smart system. Smart systems include networked sensors or distributed in space sensors, and evaluate the state of an entire structure or structural components in real time for control applications. The problem of sensor location is crucial for system identification, control, and damage detection which require accurate measurement of the responses of the system. The measured data are always inaccurate because of the existence of parameter variation and/or noise. Taking the cost of sensors into account, it is not economical to install sensors in every part of system and/or every where in the system. In such cases, a practical question that naturally arises is how to select a set with a minimum number of sensor locations from all possibilities, and how to network them, such that the data collected may provide the greatest opportunities for the detection of failures under parametric and nonparametric uncertainties. While many advances have been made in terms of sensor technology, structural reliability, and optimal sensor placement (OSP) schemes, much additional research needs to be focused on probabilistic modeling for networked sensors. Probabilistic analysis and design, as well as on OSP under uncertainty, in order to extract the maximum information about the structureŠs condition from a networked sensor while taking the uncertainties into account are key points in this research.

Similarly, studies on actuators, continuous in space with continuous or discrete sensing are limited and need detailed investigation. Probabilistic framework for studying these actuators is yet to develop. Research focus on both these aspect of continuous and discrete sensors and actuators under probabilistic framework and then to develop a robust control approach for smart system are the final goal.

Title: *Control of Distributed Parameter Systems Using Optimal Dynamic Inversion Technique*

Supervisor: Dr. Radhakant Padhi
Department of Aerospace Engineering, Indian Institute of Science, Bangalore

Description: Most of Structural elements, like, beams, cables, plates and shells are distributed parameters systems and are governed by partial differential equation (pde) of motion. Discretization of pde's to finite number of ordinary differential equation's (odes) brings in with it error due to un-modeled dynamics, especially for nonlinear systems. When controller is designed based on the discretized model, inevitable errors like controller spillover and observer spillover occur. Moreover, for nonlinear systems discretization proves to be fatal. One way to minimize these errors is to design the controller directly based on the pde of the dynamical system. Optimal dynamic inversion is one such technique which guides the structural vibration to the desired trajectory in an optimal way. In this method, dynamic inversion is coupled with optimization theory to obtain a closed form solution for controlling distributed parameter systems. The method is versatile in the sense that it can be applied to both linear and nonlinear systems and can be used to monitor both continuous and discrete actuators.

PhD Research Topic

Title: *Semi-active Control of Earthquake Induced Vibrations in Structures using MR Dampers: Algorithm Development, Experimental Verification and Benchmark Applications*

Supervisor: Prof. Ananth Ramaswamy
Department of Civil Engineering, Indian Institute of Science, Bangalore

Description: Following the 1994-Northridge and 1995-Kobe earthquakes, the interest of structural engineers to near-source ground motions has increased. Documents published after these earthquakes emphasized the issue of large base displacements because of the use of none or little isolation damping prior to these events. More recent studies investigated analytically and experimentally, the efficiency of various dissipative mechanisms to protect seismic isolated structures from recorded near-source ground motions. Resultantly, hybrid isolation, seismic isolation supplemented with damping mechanism, became the focus of current research trend in structural vibration control. Magneto-rheological (MR) dampers are found to have promising applications as a supplemental damping device along with base isolators. MR dampers operate at battery power and provide hysteretic damping to the structures.

The aim of the dissertation work has been to develop a hybrid base isolation mechanism using MR dampers as a supplemental damping device. The use of MR damper as a semi-active device involves two steps; (a) development of a model to describe the MR damper hysteretic behaviour; (b) development of a proper nonlinear control algorithm to monitor MR damper current/voltage supply.

Existing parametric models of MR damper hysteretic behaviour, e.g., simple Bouc-Wen model, fail to consider the effect of amplitude and frequency of excitation on the device. Recently reported literature has demonstrated the necessity of incorporating amplitude and frequency dependence of MR damper models. In this dissertation work we have developed a modified Bouc-Wen model to consider the effect of the amplitude of excitation. MR damper experiments with five different current levels, five amplitude and eight frequencies of excitations have been carried out to determine the parameters of the modified Bouc-Wen model.

The current/voltage supply as the input variable to the MR damper restricts the direct usage of any control algorithms developed for active control of structures. The force predicted by the available control algorithms should be mapped to equivalent current/voltage and then to be feed into the damper. Available semi-active algorithms in the literature used 'on-off' or 'bang-bang' strategy for MR applications due to nonlinear current/voltage-force relation of MR damper. The 'on-off' nature of these algorithms neither provide smooth change in MR damper current/voltage input nor consider all possible current/ voltage values within its minimum to maximum range. Secondly, these algorithms fail to consider the effect of the MR damper applied and commanded current/voltage dynamics.

In this dissertation a fuzzy based intelligent control and two model-based nonlinear control algorithms employing optimal dynamic inversion and integral backstepping techniques have been developed. The FLC has been optimized using micro-genetic algorithm and particle swarm optimization. A geometric approach, which requires fewer variables, has been developed to optimize fuzzy rule base.

The dynamic inversion based algorithm is a two stage controller. The primary controller can be any optimal control strategy in state feedback form like LQR, LQG etc., (as in case of a clipped optimal control). In the second stage current/voltage required by the MR damper to provide the control force prescribed by the primary controller has been tracked using dynamic inversion technique. For systems with multiple MR dampers, a Lagrange multiplier based approach has been formulated to determine optimal amount of current/voltage required by each of the MR.

Integral backstepping based algorithm, which alleviates the use of intermediate primary controller is also developed. Stability of the proposed controllers has been shown in Lyapunov sense and with numerical simulations. Both the model based algorithms provide a smooth change in the input current/voltage values of the MR damper, as well as consider the effect of the supplied to commanded current/voltage dynamics.

The main thrust of the thesis is the development of a hybrid isolation mechanism using MR damper for structures. This is verified through an experimental study on a three storey base isolated building. The performance of fuzzy logic based intelligent control has been explored using experimental investigation on a three storey base isolated building. GA optimized FLC is used to monitor the MR damper in real-time.

Further the application of the proposed controllers on a benchmark building; a benchmark highway bridge and a stay cables vibration reduction have been discussed. Particle swarm optimization algorithm based system identification of the building parameters (mass, stiffness, and damping) has been carried out.

Experiments with eight seismic records considering separately the fault normal and fault parallel components has been carried out. Comparison of various test results obtained from fixed base, base isolated, and four case of hybrid semi-active control (passive off, passive on, MR damper with simple FLC and MR damper with optimal FLC) has been reported.

Finally to assess the the efficacy of the proposed control algorithms, application to various international benchmark exercises is performed. A benchmark building with nonlinear base isolation and MR dampers, a benchmark base isolated highway bridge and a stay cable with sag under support motion has been considered.

Publications

(I) Book Chapter

1. **Sk. F. Ali** and A. Ramaswamy, "Developments in Structural Optimization and Applications to Intelligent Structural Vibration Control" In *Intelligent Computational Paradigms in Earthquake Engineering*, Editors: N.D. Lagros and Y. Tsompanakis, published by Idea Group Inc., 2007, Ch–6 : 101 − 121.

   also published in

   "Intelligent Information Technologies: Concepts, Methodologies, Tools and Applications", edited by Vijayan Sugumaran, (2007), Published by Idea Group Inc. (IGI), ISBN 1599049414, 9781599049410, Ch–8.7 : 2193 − 2211.

(II) Journal Publications

Published/Accepted

1. **Sk. F. Ali** and R. Padhi, "Optimal Blood Glucose Regulation of Diabetic Patients Using Single Network Adaptive Critics", *J. of Optimal Control Application and Methods*, Wiley, Accepted (to be published in 2010).

2. **Sk. F. Ali** and A. Ramaswamy, "Testing and Modeling of MR Damper and its Application to SDOF Systems using Integral Backstepping Technique", *J. of Dynamical Systems Measurements and Control*, ASME, 131(2), 021009, (DOI:10.1115/1.3072154).

3. **Sk. F. Ali** and R. Padhi, (2009), "An Account of Chronological Developments in Control of Distributed Parameter Systems", *Annual Reviews in Control*, IFAC, 33 (1) 5968, (doi:10.1016/j.arcontrol.2009.01.003).

4. **Sk. F. Ali** and R. Padhi, (2009), "Active Vibration Suppression of Nonlinear Beams Using Optimal Dynamic Inversion", *J. of Systems and Control Engineering*, Proc. IMechE, 223(5), 657-672, (doi: 10.1243/09596518JSCE688).

5. **Sk. F. Ali** and A. Ramaswamy, (2009), "Optimal Dynamic Inversion based Semi-active Control of Benchmark Bridge using MR Dampers", *Structural Control & Health Monitoring*, 16(5), 564-585, (doi:10.1002/stc.325).

6. **Sk. F. Ali** and A. Ramaswamy, (2009), "Hybrid Structural control using Magnetorheological Dampers for Base Isolated Structures", *Smart Materials & Structures*, 18(5)-055011, (doi: 10.1088/0964-1726/18/5/055011).

7. **Sk. F. Ali** and A. Ramaswamy, (2008), "Optimal Fuzzy Logic Control for MDOF Structural Systems Using Evolutionary Algorithm", *Engineering Applications of Artificial Intelligence, IFAC*, 22(3), 407 − 419 (doi:10.1016/j.engappai.2008.09.004).

8. **Sk. F. Ali** and A. Ramaswamy, (2008), "GA optimized FLC driven semi-active control for Phase II smart nonlinear base isolated benchmark building", *Structural Control & Health Monitoring*, 15(5), 797 − 820 (doi:10.1002/stc.272).

Manuscripts under review

1. **Sk. F. Ali** and A. Ramaswamy, "Optimal Fuzzy Logic based Hybrid Isolation Systems for Buildings: an Experimental and Numerical Study", *J. of Structural Engineering*, ASCE.

2. P. Samui and **Sk. F. Ali**, "A SVM Approach to the Confinement Efficiency of RC Columns with Rectangular Ties", *International J. of Structural Engineering.*

Under preperation

1. **Sk. F. Ali** and A. Ramaswamy, "A Review on Magnetorheological Damper Modeling and Semi-active Control Algorithms",

2. **Sk. F. Ali** and A. Ramaswamy, "Semi-active Vibration control of Stay Cables using MR Dampers",

(III) Refereed Conference Papers

International

1. **Sk. F. Ali** and S. Adhikari, "Control of a class of non-linear stochastic partial differential equations", *IV European Conference on Computational Mechanics (ECCM-*2010*)*, Paris, France, May 16 – 21, 2010.

2. **Sk. F. Ali**, C. Delattre, M. Boutayeb, C. Fonte and F. Asllanaj, "An Approximate Modeling of 1D Transient Heat Transfer in a Gray Participating Medium for Real-time Control Applications", *American Control conference (ACC-*2010*)*, IEEE, 2010.

3. **Sk. F. Ali** and S. Adhikari, "Adaptive Backstepping based MR Damper Monitoring for Structural Applications", *SPIE Conference (SPIE-*2010*)*, 2010.

4. **Sk. F. Ali** and Radhakant Padhi, "Optimal Blood Glucose Regulation using Single Network Adaptive Critics", *IEEE Multi-conference on Systems and Control (MSC-*2009*)*, IEEE, St. Petersburg, Russia, October $1^{st} - 3^{rd}$, July 8 – 10, 2009.

5. **Sk. F. Ali** and P. Samui, "Confinement Efficiency of R C Columns with Rectangular Ties: A SVM Approach", *Special session on Natural Computing in Infrastructure Engineering and Management, 3^{rd} Indian International Conference on Artificial Intelligence (IICAI-07)*, Pune, India, December 17 – 19, 2007.

6. **Sk. F. Ali** and Radhakant Padhi, 'Active Vibration Suppression of One dimensional Nonlinear Structures Using Optimal Dynamic Inversion", *IEEE Multi-conference on Systems and Control (MSC-*2007*)*, IEEE, Singapore, October $1^{st} - 3^{rd}$, 2007.

7. **Sk. F. Ali** and A., Ramaswamy, "GA Optimized Semi-Active Adaptive Fuzzy Logic Control for Stay Cable Vibration", *Structural Engineering World Congress (SEWC-2007)*, Bangalore, India, November 3 – 7, 2007.

8. **Sk. F. Ali**, A. Ramaswamy, and A. K. Agrawal, "Semi-active Base isolation System for Buildings using MR Dampers", *World forum on Smart Materials & Smart Structures Technology (SMSST 07)*, Chongqing & Nanjing, China, May 3 – 7, 2007.

9. **Sk. F. Ali** and A., Ramaswamy, "FLC-MR Damper Control of Stay Cable Nonlinear Vibration", *Civil Engineering in the New Millennium: Opportunities and Challenges (CENeM)*, Bengal Engineering and Science University, Kolkata, India, January 11 – 14, 2007.

10. **Sk. F. Ali** and A., Ramaswamy, "FLC Based Semi-Active Control of Buildings using Magnetorheological Dampers", 2^{nd} *International Congress on Computational Mechanics and Simulation, (ICCMS-07)*, Indian Institute of Technology , Guwahati, India, December 10 – 12, 2006.

11. **Sk. F. Ali** and A., Ramaswamy, "Benchmark Control Problem for Highway Bridge based on FLC", *Proceedings of* 2006 *Structures Congress, ASCE and SEI*, St. Louis MO, USA, May, 2006.

12. **Sk. F. Ali** and Radhakant Padhi, "Vibration Control of Nonlinear Beams Using Optimal Dynamic Inversion with Discrete Actuators", 2^{nd} *International Congress on Computational Mechanics and Simulation, (ICCMS-07)*, Indian Institute of Technology , Guwahati, India, December 10 – 12, 2006.

13. **Sk. F. Ali** and Radhakant Padhi, "Active Vibration Suppression of Beams with Discrete Actuators Using Optimal Dynamic Inversion", *9th International Conference on Control, Automation, Robotics and Vision(ICARCV-*06*)*, IEEE, Singapore, December, 2006.

14. **Sk. F. Ali** and A., Ramaswamy, "Non-linear Modeling and Control of Cable-stay system under Tower flexibility using Passive and Semi-active Control", *Proceedings of the Structural Engineering Convention (SEC-*2005*)*, IISc Bangalore, India, December 8 – 10, 2005, page-333.

National

1. **Sk. F. Ali**, "Backstepping Based Magnetorheological Damper Monitoring for Structural Control", *First Annual Students Symposium*, Dept. of Civil Engineering, IISc, Bangalore, India, July910, 2008, (**Students Best Presentation Award**).

2. **Sk. F. Ali** and A. Ramaswamy, "Optimal Preview Active Control of Structures During Earthquakes Using Feed-Back and Feed-Forward data", *National Conference on Recent Advancement on Structural Engineering, (NCRASE-*2006*)*, JNTU-Kakinada, AP, India, Febraury, 2006.

3. **Sk. F. Ali** and A. Ramaswamy, "Review and Development of Vibration Control Strategies for Cable Supported Bridges", *National Symposium on Structural Dynamics, Random Vibration and Earthquake Engineering (NSDD-*2005*)*, IISc Bangalore, July 2223, 2005.

Graduate Course-Work

Credited

- Mathematical methods in Engineering: S-Grade
- Analysis and Synthesis of Linear Control Systems: S-Grade
- Finite Element Structural Analysis: S-Grade

- Structural Dynamics: A-Grade
- Solid Mechanic: A-Grade
- Artificial Neural Networks for Engg. Appl.: A-Grade

Audited
Continuum Mechanics; Structural Reliability; Stochastic Structural Dynamics; Structural System Identification; Wavelets through Linear Algebra; Advanced Optimal Control Design; Structural Optimization; Nonlinear Control Synthesis; Nonlinear Dynamics.

Membership

Student member **IEEE** (*Control System Society*) Bangalore Section

Student member **ASCE**

Awards and Scholarships

Newton International Fellowship (Royal Academy of Engineering, UK to do postdoctoral studies at Swansea University), (Jan 2010 – Dec 2011)

Students Best Presentation Award (Dept. of Civil Engg., IISc, Bangalore, India), (2008)

Fifth Prize *All Bengal Sit and Draw Contest* (for age group under 15), (1995)

Second Prize *Fevicol Fevi Fairy's Think 'n' Stick Contest in School*, (1991)

In Research: *Ministry of Human Resource Development, Govt. of India*

In Engineering, Merit Scholarship: *Board of Wakfs, Govt. of West Bengal* and *Jyotirmoy Bikash Memorial Endowment Fund Society*

In Higher Secondary, Merit Scholarship: *Muslim Progressive Society*

In Secondary School, Merit Scholarship: *Muslim Progressive Society*

Other Activities

Organizing Committee: First Annual Students Symposium, Dept. of Civil Engg., Indian Institute of Science, 9^{th}-10^{th} *July, 2008*

Organizing Committee: Weekly Students Seminar Series, Dept. of Civil Engg., Indian Institute of Science

Student Organizing Committee: Structural Engineering Convention, Dept. of Civil Engg., Indian Institute of Science, 9^{th}-10^{th} *Dec, 2005*,

Personal Details

D.O.B: 29^{th} January 1980

Sex: Male

Marital Status: Married

Nationality: Indian

References

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