Srinivasa M. Salapaka

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Education

Indian Institute of Technology, Madras	B.Tech.	Mechanical Engineering	1995
University of California, Santa Barbara	MS	Mechanical Engineering	1997
University of California, Santa Barbara	PhD	Mechanical Engineering	2002

Academic Experience

2017 – Present	Professor, University of Illinois, Urbana-Champaign
2010 – 2017	Associate Professor, University of Illinois, Urbana-Champaign
2013 -2014	Control Researcher at Google Inc. (via Adecco)
2004 – 2010	Assistant Professor, University of Illinois, Urbana-Champaign
2007 – Present	Affiliate in Coordinated Science Laboratory
2006 – Present	Affiliate in Industrial & Enterprise Systems Engineering
2002-2003	Postdoctoral Associate: Massachusetts Institute of Technology
1995 – 2002	Research Assistant: University of California, Santa Barbara

Honors/Recognitions

- Plenary Speaker at the International Conference in Nonlinear Problems in Aviation and Aerospace (ICNPAA) lecture titled "Combinatorial Optimization Problems on Networks: A Maximum-Entropy-Principle Based Framework", July 03, 2018.
- Plenary/Keynote Speaker in 28th International Conference and Expo on Nanoscience and Technology, lecture titled "Micro/Nanoscale Research: A Control Systems Viewpoint", Barcelona, Spain, November 26, 2018.
- ASME Fellow, 2015
- National Science Foundation CAREER award, March 2005.
- Engineering Council for Excellence in Advising, University of Illinois, April 2013.
- List of Teachers ranked excellent by students, Fall 2007, Spring 2010, Fall 2011, Spring 2012, Fall 2015, Spring 2016, Fall 2016, Fall 2018, Spring 2019.
- Student – Mayank Baranwal Finalist, best student paper award, Indian Control Conference, 2018 for the paper "Weighted-Kernel Deterministic Annealing: A Maximum-Entropy Principle Approach for Shape Clustering, written with my student M. Baranwal. This paper was judged to be in top three papers in the conference.
- "5th most downloaded article in June and August 2008" for the article `` Robust Control of a Parallel- Kinematic Nanopositioner," as announced by ASME Journal of Dynamic Systems, Measurement, and Control, 2008.
- Journal article "Sample-profile Estimate for Fast Atomic Force Microscopy," Applied Physics Letters highlighted in the Microscopy Focus section in the Photonics Spectra magazine

Areas of Specialization

- Control systems theory and applications, scanning probe microscopy, intracellular transport, engineered micro/nanoscale transport, control of power electronics, smart power grids, precision positioning, combinatorial optimization, algorithm for combinatorial data clustering and resource allocation, aggregation of graphs and Markov chains, analysis and synthesis of algorithms in numerical algebra.

Research Highlights

- ***Micro/Nanoscale/intracellular investigation and instrumentation***
  - developed a control design framework for quantifying, designing, and implementing a high-precision high-bandwidth and robust positioning system
  - demonstrated precision positioning with subnanometer resolution using our framework, where the design appropriately traded bandwidth for resolution which enabled studying 5 angstrom periodic stick-slip motion on mica lattice
  - demonstrated over 300 times improvement in the bandwidth, when compared to existing commercial designs, and at the same time practically eliminated the hysteresis and creep, the effects of piezoactuation
  - demonstrated the first multi-input multi-output control design for micro-electro mechanical systems (MEMS) based nanopositioning stages
  - demonstrated a new method for imaging in atomic force microscopy which enables accurate sample-profile imaging that showed a 500% improvement in contact-mode and over 70% improvement in dynamic mode in imaging bandwidth over the pre-existing approaches. This result debunked one of the perceived limitations that imaging bandwidth cannot be higher than the control (regulation, disturbance rejection) bandwidth.
  - demonstrated a method that achieved simultaneous correction, in real time, for the imaging artifacts caused by cantilever and photosensor misalignments as well as misinterpretations in relative lateral position of the cantilever tip with respect to the sample due to the tip-sample stick in AFM.
  - developing a new method of atomic force microscope (AFM) imaging that exploits the recent rapid advances in fabrication of piezoactuated positioning mechanisms that are much faster with bandwidth on the order of 30 kHz (about 50 times faster than the positioning systems in the commercial AFMs).
  - demonstrated a feedback based control that circumvents the limitations of existing active force (optical-tweezer) clamps, which has enabled real-time protein step estimation for step sizes as small as 8 nm with dwell time of >5 ms without sacrificing force regulation
  - developed a systematic methodology for designing open-loop Brownian ratchet mechanisms that optimize velocity and efficiency of particle transport; demonstrated over 300% improvement over open loop efficiency
  - developed a systematic framework for designing the control for fine positioning (scanning) stages of X-ray microscopes; implemented on the beamline at advanced photon source, Argonne National Lab; enabled and demonstrated a flyscan mode where bandwidth was improved by over 450 times when compared to existing the step scan.

- ***Clustering, Classification, and Aggregation of Data***
  - developed scalable algorithms for data clustering with dynamic, communication, and capacity constraints
  - demonstrated the framework by applying it to solving the lead-compound representation problem in combinatorial drug discovery; demonstrated on dynamic coverage (resource allocation while tracking dynamic clusters) problems that naturally allows for quantification of inter-cluster and intracluster dynamics, achieving the coverage as well as tracking objectives, and enables inclusion of certain dynamic constraints not possible; on applications require routing and scheduling of multiple vehicles from a depot (or multiple depots) to meet demands at multiple locations, under time-window constraints
  - demonstrated algorithms for network model aggregation, required especially for biological networks, which require aggregation of large weighted directed graphs into smaller directed graphs whose nodes and corresponding links carry aggregated information of the underlying

graphs; applied these algorithms to complex causality-network diagrams of neurons, called influence diagrams and the resulting aggregated network agreed with neuroscientists' intuitive understanding of the original network.

- developed an algorithm to cluster dynamic data and aggregate dynamic graphs and Markov chains
- developed an algorithm to solve the apex hard multiway k-cut problem; showed provable improvements over existing algorithms
- developed an algorithm for solving Sparse Linear Regression problem; enabled cases that are not possible with compression sensing methods
- developed a framework for sequential decision making problems including markov decision processes (MDPs) and reinforcement learning problems; showed faster convergence than Q, soft Q, and other learning algorithms

- ***Power Systems and Control***
  - developed a comprehensive framework for controlling power electronics (converters and inverters) for managing electrical viability and power sharing between different sources that guarantee performance under uncertainties in load demands and schedules. This architecture also incorporates communication between controllers (at different sources) which gives a graceful degradation of performance with loss in communication network
  - developed an optimal control based distributed design methodology that gives provable robust power sharing between different sources and voltage regulation performance at the grid while still avoiding analytical complexities due to distributed structure
  - developed a method to analyze and cluster an electrical power network with many buses into pre-specified number of groups such that buses within each group have a similar influence over the remainder of the network.
  - developed a control framework for analysis, and net-load management of dc microgrids
  - developed a control framework for analysis, and net-load management of ac microgrids
  - developed a high-bandwidth control design for fast curtailment of photovoltaic (solar) units

Editorships

- Associate Editor, ASME Journal of Dynamic Systems, Measurement and Control, 2012-2019
- Associate Editor, Proceedings of the Indian Control Conference, 2014-date
- Associate Editor, Proceedings of the IEEE Conference on Decision and Control, 2007-2019
- Associate Editor, Proceedings of the IEEE American Control Conference, 2007-2019

Invited Book Chapters

1. Mashrafi S., C. Preissner, and S. Salapaka (2019) Sensor Drift Rejection in X-Ray Microscopy: A Robust Optimal Control Approach. In: Baillieul J., Samad T. (eds) Encyclopedia of Systems and Control. Springer, London, 2020
2. C. L. Beck, S. Salapaka, P. Sharma and Y. Xu. "Dynamic Coverage and Clustering: A Maximum Entropy Approach," Distributed Decision Making and Control, Lecture Notes in Control and Information Sciences 417, pp. 215–243, Editors R. Johansson and A. Rantzer, .Springer-Verlag, 2012 (ISBN 978-1-4471-2265-4).
3. C. Lee, G. Mohan, and S. Salapaka, "2DOF Control Design for Nanopositioning," in Control Technologies for Emerging Micro and Nanoscale Systems, Dr. E. Eleftheriou and Dr. S.O.R. Moheimani (Eds.), Lecture Notes in Control and Information Sciences 413, Springer-Verlag, Berlin, ISBN 978-3-642-22172-9, 2011.
4. S. Salapaka and M. Salapaka, "Atomic Force Microscopy: Principles and Systems Viewpoint

Enabled Methods," in Feedback Control at Micro-and Nano-Scales: MEMS to Atoms," Dr. J. Gorman and Dr. B. Shapiro, eds., Springer, (ISBN-10: 1441958312, ISBN-13: 978-1441958310), 2011.

5. P. Sharma, S. Salapaka, and C. Beck, "A Scalable Approach to Combinatorial Library Design," a chapter in a book in Methods in Molecular Biology (MiMB) series on Combinatorial Chemical Library Design, Humana Press, series editor John M. Walker, editor Joe Zhongxiang Zhou, 2010 (ISBN 978-1-60761-930-7).
6. A. Sebastian, S. Salapaka, and M. V. Salapaka, "System Tools Applied to Microcantilever Based Devices," in Multidisciplinary Research in Control: The Mohammed Dahleh Symposium 2002, L. Giarre and B. Bamieh, eds., Lecture Notes in Control and Information Sciences N. 289, Springer-Verlag, Berlin 2003, ISBN 3-540-00917-5.

Refereed Journals (Selected)

1. Mashrafi, S., C. Preissner, and S. Salapaka, Optimal Control for X-ray Microscopes,accepted in IEEE/ASME Transactions on Mechatronics, 2020
2. Baranwal, M. and S. Salapaka, "Clustering and Supervisory Voltage Control in Power Systems", International Journal of Electrical Power and Energy Systems, 109 (2019): 641-651, 2019.
3. Baranwal, M., Askarian, A., Salapaka, S.M. and Salapaka, M.V., Distributed Architecture for Robust and Optimal Control of DC Microgrids. IEEE transactions on Industrial Electronics, 66.4, 3082-3092, 2019.
4. Baranwal, M., R. Gorugantu, and S. Salapaka, "Robust Atomic Force Microscopy using Multiple Sensors," Review of Scientific Instruments,87(8), p.083704, 2016.
5. Baranwal, M., R. S. Gorugantu, and S. M. Salapaka. "Fast and robust control of nanopositioning systems: Performance limits enabled by field programmable analog arrays," Review of Scientific Instruments 86, no. 8, 085004, 2015.
6. Roychowdhury, S., G.Saraswat, S.Salapaka, and M.Salapaka. "On control of transport in Brownian ratchet mechanisms," Journal of Process Control 27 (2015): 76-86.
7. Lee, C., and S. M. Salapaka. "Model based control of dynamic atomic force microscope," Review of Scientific Instruments 86, no. 4 (2015): 043703.
8. Y. Xu, S. Salapaka, and C. Beck, "Aggregation of Graph Models and Markov Chains by Deterministic Annealing," The IEEE Transactions on Automatic Control, 59(10), 2807-2812, October 2014.
9. Zhang,X., B. Koo, S. Salapaka, J. Dong*, and P. Ferreira,"Robust Control of a MEMS Probing Device" IEEE/ASME Transactions on Mechatronics, Vol 19(1), 100-108, February 2014
10. Xu, Y., S. Salapaka, and C. Beck, "Clustering and Coverage Control for Systems With Acceleration-Driven Dynamics," The IEEE Transactions on Automatic Control, 1342-1347, 59(5), May 2014.
11. S. Roychowdhury, T. Aggarwal, S. Salapaka, and M. Salapaka, "High bandwidth optical force clamp for investigation of molecular motor motion," Applied Physics Letters 103, 153703 (2013).
12. N. Kale and S. Salapaka, "Maximum Entropy Principle based Algorithm for Simultaneous Resource Location and Multi-hop Routing in Multi-agent Networks," IEEE Transactions on Mobile Computing, vol. 11, no. 4, pp. 591-602, Apr. 2012.
13. P. Sharma, S. Salapaka, and C. Beck, "Entropy-based Framework for Dynamic Coverage and Clustering Problems," IEEE Transactions on Automatic Control, Vol 57, No. 1, 135-150, January 2012.
14. Koo B., X. Zhang, J. Dong, S. Salapaka, and P. Ferreira, "A 2 Degree-of-Freedom SOI-MEMS Translation Stage with Closed Loop Positioning", IEEE/ASME Journal of Microelectromechanical Systems, Vol. 21, no. 1, 13-22, February 2012
15. C. Lee and S. Salapaka, "Robust Broadband Nanopositioning: Fundamental Tradeoffs, Analysis and Design in Two Degree of Freedom Control Framework," Nanotechnology, 20,

035501, 2009.

16. J. Dong, S. Salapaka, and P. Ferreira, “Robust Control of a Parallel Kinematic Nano-Positioner,” ASME Journal of Dynamic Systems, Measurement and Control, Vol 130, 041007(1-15), July 2008.
17. Shegaonkar, A. C. and S. M. Salapaka, “Making High Resolution Positioning Independent of Scan Rates: a Feedback Approach,” Applied Physics Letters, 91:20, Art No. 203513, 2007
18. S. Salapaka, T. De and A. Sebastian, A robust control based solution to the sample-profile estimation problem in fast atomic force microscopy, International Journal for Robust and Nonlinear Control , Volume 15 (16), 821-837, November 2005.
19. A. Sebastian and S. Salapaka, Design Methodologies for Robust Nano-positioning, IEEE Transactions on Control Systems Technology, Volume 13 (6), 868-876, November 2005.
20. S. Salapaka, A. Sebastian, J.P. Cleveland and M.V. Salapaka, High bandwidth nano-positioner: A robust control approach , Review of Scientific Instruments, Volume 73, No. 9, Pages 3232-3241, September, 2002.

Workshops Organization

1. Co-Organizer, "Enabling grid of the future," American Control Conference, 2015.
2. Co-Organizer, "Algorithms for Data and Graph Clustering, Classification & Aggregation," Allerton Conference, October 2012.
3. Session Organizer, “Dynamic Clustering and Coverage Algorithms,” 47th Annual Allerton Conference on Communication, Control, and Computing, September 2009.
4. Organizer of Symposium at SES, “Modeling, Analysis, and Instrumentation in Scanning Probe Microscopy,” October 12-15, 2008.
5. Session Organizer and Co-Chair, “Modelling and Control of MEMS in Industrial Applications,” 2005 American Control Conference, Portland, OR, Jun. 2005.
6. Organizer, Co-Chair and Presenter for two sessions “Symposium on Dynamics and Control of Micro and Nanosystems,” 2005 ASME International Mechanical Engineering Congress and Exposition, Orlando, FL, DSC-1A and 2B, Nov. 2005.

Invited Seminars (Selected)

1. "Markov Decision Processes and Sparse Linear Regression: A Combinatorial Optimization Viewpoint”, Invited Speaker, 9th Midwest Workshop on Control and Game Theory,Institute for Mathematical Applications, the University of Minnesota, Twin Cities on April 25-26 2020.
2. Plenary Speaker at the International Conference in Nonlinear Problems in Aviation and Aerospace (ICNPAA) lecture titled "Combinatorial Optimization Problems on Networks: A Maximum-Entropy-Principle Based Framework", July 03, 2018.
3. "Routing, Resource Allocation, and Scheduling Problems: A Maximum Entropy Principle Approach," invited for the NTU-UIUC Forum on Smart Mobility, Autonomous & Connected Vehicles to Taipei, Taiwan.
4. Plenary/Keynote Speaker in 28th International Conference and Expo on Nanoscience and Technology, lecture titled "Micro/Nanoscale Research: A Control Systems Viewpoint", Barcelona, Spain, November 26, 2018.
5. "Micro/Nanoscale Investigation: feedback to rescue," workshop on Quantum and Nano Control, theme of Control theory and applications at Institute for Mathematics and its Applications, Minneapolis, April 11-16, 2016.
6. "Graph Aggregation and Dynamic Coverage: An Entropy Based Approach," The 4th Midwest Workshop on Control and Game Theory, and the ECE seminar series, Ames, Iowa State University, April 26, 2015.
7. “Scanning Probe Microscopy: A Control Systems Perspective," Center for Control, Dynamical Systems and Computation, University of California, Santa Barbara, Jan 31, 2014.
8. “Control Techniques for High-Speed Dynamic-Mode Imaging in Atomic Force Microscopes,"

invited special presentation in the symposium on Measurement and Control in Micro- and Nanosystems at the ASME International Design and Engineering Technical Conference held in Chicago, Illinois from 12-15 August 2012.

9. "Toward a New High-Speed Dynamic Mode Imaging in Atomic Force Microscopy," 2nd Workshop on Dynamics and Control of Micro and Nanoscale Systems, The University of Newcastle, NSW, Australia, February 24, 2012.
10. "A Control Systems Perspective to Nanpositioning," Advance Photon Source Center, Argonne National Lab, December 08, 2011.
11. " Fundamental Limitations and Optimal Control Design for Nanopositioning," Workshop on Dynamics and Control of Micro and Nanoscale Systems, IBM Research – Zurich, Ruschlikon, Switzerland, December 10-11, 2009.
12. "Systems tools in Scanning Probe Microscopy," NSF workshop on Research Challenges for Nanomanufacturing Systems, NSF Headquarters, Arlington, Virginia, February 11-12, 2008.
13. "A Maximum-Entropy-Principle Based Approach for Dynamic coverage and clustering problems," Decision and Control Lab, Georgia Institute of Technology, October 2010.
14. "A Control Systems Perspective for Nanopositioning," Brookhaven National Laboratory Upton, NY, Sep 22, 2009.
15. "Dynamic Coverage, Routing, and Coarse Quantization Problems – A Maximum Entropy Principle Approach," Department of Aerospace Engineering, Texas A & M University, November 19, 2009.
16. "Understanding Fundamental Limitations in Nanoim¬aging and Nanopositioning," Control Science and Dynamical Systems (CSDy) Seminar, Department of Electrical and Computer Engineering, University of Minnesota, October 20, 2008.
17. "Maximum-Entropy-Principle Based Algorithms for Dynamic Coverage, Routing, and Coarse Quantization Problems," Center for Control, Dynamical Systems and Computation, University of California, Santa Barbara, October 31, 2008.
18. "Dynamic Coverage, Routing, and Coarse Quantization Problems – A Maximum Entropy Principle Approach," Department of Aeronautics and Astronautics, Stanford University, November 5, 2008.
19. "Scanning Probe Microscopy – A Control Systems Perspective," Department of Mechanical Engineering, University of California, Berkeley, November 4, 2008.
20. Systems tools in scanning probe microscopy, in Mechanical Engineering Seminar Series at the University of Michigan, Ann Arbor, September 28, 2007.
21. Coarse Quantization as a Resource Allocation Problem - A Maximum Entropy Approach, Decision, Control and Optimization Seminar Series, Coordinated Sciences Laboratory, University of Illinois , Urbana Champaign, October 25, 2006.

Patents

Patent number: 9712040,Virtual impedance shaping, Filed: December 30, 2014, Date of Patent: July 18, 2017, Assignee: Google Inc. Inventors: Sangsun Kim, Srinivasa Murthy Salapaka, Murti V. Salapaka, Subhrajit Roychowdhury.