

# Curriculum vitae: Piyush Grover

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## Employment

- 08/19– Assistant Professor, Mechanical and Materials Engineering, University of Nebraska-Lincoln, Nebraska, USA
- 04/19– Senior Principal Research Scientist, MERL
- 06/19– Principal Research Scientist, MERL
- 04/15–
- 03/19– Research Scientist, Control and Dynamical Systems Group, Mitsubishi Electric Research Laboratories ([MERL](#)), Cambridge, MA, USA
- 07/10–
- 03/15

## Education

- July 2010 PH.D. in Engineering Mechanics, Virginia Tech, Blacksburg, VA  
**Thesis:** Finding and exploiting structure in complex systems via geometric and statistical methods  
**Advisor:** Shane Ross
- June 2005 B.TECH in Mechanical Engineering, Indian Institute of Technology (IIT), Guwahati, India

## External Grants at University of Nebraska-Lincoln : \$780K total (all as PI), \$550K personal share

1. *Phase space geometry of critical transitions in collective behavior modeled by mean field type control problems* (8/2021-7/2024). Sponsor: National Science Foundation - Dynamics, Control and System Diagnostics (NSF-CMMI-DCSD). Amount \$311,553 (Role: PI, Personal share: 100%)
2. *Dynamics and control of active nematics using nonlinear reduced-order models* (8/2021-7/2024). Sponsor: Department of Energy, Basic Energy Sciences (DOE-BES). Amount \$450,000. Role: PI, Personal share: 50%. Co-Is: Jae Sung Park (UNL), Michael Norton (RIT)
3. *PDE-based control of multi-agent systems* (9/2019-6/2022). Sponsor: Mitsubishi Electric Research Labs (MERL). Amount: \$16,000 (Role: PI, Personal share: 100%)

## Invited Talks

Telluride Science Research Center-Colorado (Active matter workshop), Brandeis University, Fields Institute (U. Toronto), UC San Diego, U. Nebraska-Lincoln, U. Alabama-Tuscaloosa

## Publications, Presentations and Patents

\* = Ph.D. student at UNL, \*\* = Postdoctoral researcher at UNL, † = Research intern at MERL, all directly supervised by Piyush Grover

### Journal articles

#### Submitted

- [1] S. Vijayshankar†, A. Chakrabarty, S. Nabi, and P. Grover, “Reduced-order model and observer co-design for turbulent flows,” Submitted to *IFAC Journal of Systems and Control*, 2021.
- [2] C. Wagner\*\*, M. M. Norton, J. S. Park, and P. Grover, “Exact coherent structures and phase space geometry of pre-turbulent 2D active nematic channel flow,” Submitted to *Physical Review Letters*, [arxiv.org/abs/2109.06455](https://arxiv.org/abs/2109.06455), 2021.
- [3] S. Nabi, P. Grover, and C. Caulfield, “Comparison of robust preconditioned one-shot methods and adjoint-looping for optimising Reynolds-averaged turbulent flows,” *Computers and Fluids* in revision, 2020.

#### Accepted/Published

- [4] M. Norton, P. Grover, M. Hagan, and S. Fraden, “Optimal control of active nematics,” *Physical Review Letters*, 2020, **Chosen as Editor’s Suggestion**. DOI: [10.1103/PhysRevLett.125.178005](https://doi.org/10.1103/PhysRevLett.125.178005).
- [5] K. Bakshi†, P. Grover, and E. Theodorou, “On mean-field games for agents with Langevin dynamics,” *IEEE Transactions on Control of Network Systems*, 2019. DOI: [10.1109/TCNS.2019.2896975](https://doi.org/10.1109/TCNS.2019.2896975).
- [6] M. A. Khodkar, P. Hassanzadeh, S. Nabi, and P. Grover, “Reduced-order modeling of fully turbulent buoyancy-driven flows using the green’s function method,” *Physical Review Fluids*, vol. 4, 1 2019, **Chosen as Editor’s Suggestion**. DOI: [10.1103/PhysRevFluids.4.013801](https://doi.org/10.1103/PhysRevFluids.4.013801).
- [7] S. Nabi, P. Grover, and C. Caulfield, “Nonlinear optimal control policies for buoyancy-driven flows in the built environment,” *Computers and Fluids*, 2019.
- [8] K. Berntorp and P. Grover, “Feedback particle filter with data-driven gain-function approximation,” *IEEE Transactions on Aerospace and Electronic Systems*, 2018. DOI: [10.1109/TAES.2018.2807559](https://doi.org/10.1109/TAES.2018.2807559).
- [9] K. Elamvazhuthi† and P. Grover, “Optimal transport over nonlinear systems via infinitesimal generators on graphs,” *Journal of Computational Dynamics*, 2018. DOI: [10.3934/jcd.2018001](https://doi.org/10.3934/jcd.2018001).
- [10] K. Elamvazhuthi†, P. Grover, and S. Berman, “Optimal transport over discrete-time nonlinear systems using stochastic feedback laws,” *IEEE Control Systems Letters*, 2018. DOI: [10.1109/LCSYS.2018.2855185](https://doi.org/10.1109/LCSYS.2018.2855185).
- [11] P. Grover, K. Bakshi†, and E. Theodorou, “A mean-field game model for homogeneous flocking,” *Chaos: An Interdisciplinary Journal of Nonlinear Science*, 2018. DOI: [10.1063/1.5036663](https://doi.org/10.1063/1.5036663).

- [12] A. Kuang, N. Cao, A. Creely, *et al.*, “Conceptual design study for heat exhaust management in the ARC fusion pilot plant,” *Fusion Engineering and Design*, 2018. DOI: [10.1016/j.fusengdes.2018.09.007](https://doi.org/10.1016/j.fusengdes.2018.09.007).
- [13] P. Grover and K. Elamvazhuthi†, “Optimal perturbations for nonlinear systems using graph-based optimal transport,” *Communications in Nonlinear Science and Numerical Simulation*, 2017. DOI: [10.1016/j.cnsns.2017.09.020](https://doi.org/10.1016/j.cnsns.2017.09.020).
- [14] B. Kramer†, P. Grover, P. Boufounos, S. Nabi, and M. Benosman, “Sparse sensing and DMD-based identification of flow regimes and bifurcations in complex flows,” *SIAM Journal on Applied Dynamical Systems*, vol. 16, no. 2, pp. 1164–1196, 2017. DOI: [10.1137/15M104565X](https://doi.org/10.1137/15M104565X).
- [15] S. Nabi, P. Grover, and C. P. Caulfield, “Adjoint-based optimization of displacement ventilation flow,” *Building and Environment*, 2017. DOI: [10.1016/j.buildenv.2017.07.030](https://doi.org/10.1016/j.buildenv.2017.07.030).
- [16] A. Tripathi†, P. Grover, and T. Kalmár-Nagy, “On optimal performance of nonlinear energy sinks in multiple-degree-of-freedom systems,” *Journal of Sound and Vibration*, vol. 388, pp. 272–297, 2016. DOI: [10.1016/j.jsv.2016.10.025](https://doi.org/10.1016/j.jsv.2016.10.025).
- [17] Y. Sato, P. Grover, and S. Yoshikawa, “Design of low fuel trajectory in interior realm as a backup trajectory for Lunar exploration,” *Transactions of Japan Society for Aeronautical and Space Sciences*, vol. 12, no. ists29, 2014. DOI: [10.2322/tastj.12.Pd\\_47](https://doi.org/10.2322/tastj.12.Pd_47).
- [18] P. Grover, S. D. Ross, M. A. Stremler, and P. Kumar, “Topological chaos, braiding and bifurcation of almost-cyclic sets,” *Chaos: An Interdisciplinary Journal of Nonlinear Science*, vol. 22, no. 4, p. 043 135, 2012. DOI: [10.1063/1.4768666](https://doi.org/10.1063/1.4768666).
- [19] M. A. Stremler, S. D. Ross, P. Grover, and P. Kumar, “Topological chaos and periodic braiding of almost-cyclic sets,” *Physical review letters*, vol. 106, no. 11, p. 114 101, 2011. DOI: [10.1103/PhysRevLett.106.114101](https://doi.org/10.1103/PhysRevLett.106.114101).
- [20] P. Grover and S. D. Ross, “Designing trajectories in a planet-moon environment using the controlled Keplerian map,” *AIAA Journal of guidance, control, and dynamics*, vol. 32, no. 2, pp. 437–444, 2009. DOI: [10.2514/1.38320](https://doi.org/10.2514/1.38320).

### Peer-reviewed conference proceedings

- [21] K. Bakshi†, E. A. Theodorou, and P. Grover, “Stabilizing optimal density control of nonlinear agents with multiplicative noise,” in *IEEE Conference on Decision and Control (CDC)*, IEEE, 2020.
- [22] U. Kalabic, P. Grover, and S. Aeron, “Optimization-based incentivization and control scheme for autonomous traffic,” *IEEE Intelligent Vehicles Symposium*, 2020.
- [23] S. Vijayshankar†, S. Nabi, A. Chakraborty, P. Grover, and M. Benosman, “Dynamic mode decomposition and robust estimation: Case study of a 2D turbulent Boussinesq flow,” *American Control Conference (ACC)*, 2020.
- [24] P. Grover, “Stability analysis in mean-field games via an Evans function approach,” in *ASME Dynamic Systems and Control Conference (DSCC)*, 2018. DOI: [10.1115/DSCC2018-8926](https://doi.org/10.1115/DSCC2018-8926).
- [25] N. G. Nilsson, P. Grover, and U. Kalabic, “Assignment and control of two-tiers of traffic,” in *IEEE Conference on Decision and Control (CDC)*, IEEE, 2018.
- [26] Y. Pan, A.-m. Farahmand, M. White, S. Nabi, P. Grover, and D. Nikovski, “Reinforcement learning with function-valued action spaces for partial differential equation control,” in *Proceedings of the 35th International Conference on Machine Learning (ICML)*, ser. Proceedings of Machine Learning Research, vol. 80, PMLR, 2018, pp. 3986–3995. [Online]. Available: <http://proceedings.mlr.press/v80/pan18a.html>.

- [27] M. Benosman, B. Kramer†, P. T. Boufounos, and P. Grover, “Learning-based reduced order model stabilization for partial differential equations: Application to the coupled burgers’ equation,” in *American Control Conference (ACC)*, IEEE, 2016, pp. 1673–1678. DOI: [10.1109/ACC.2016.7525157](https://doi.org/10.1109/ACC.2016.7525157).
- [28] K. Berntorp and P. Grover, “Data-driven gain computation in the feedback particle filter,” in *American Control Conference (ACC)*, IEEE, 2016, pp. 2711–2716. DOI: [10.1109/ACC.2016.7525328](https://doi.org/10.1109/ACC.2016.7525328).
- [29] A.-m. Farahmand, S. Nabi, P. Grover, and D. N. Nikovski, “Learning to control partial differential equations: Regularized fitted q-iteration approach,” in *IEEE Conference on Decision and Control (CDC)*, IEEE, 2016, pp. 4578–4585. DOI: [10.1109/CDC.2016.7798966](https://doi.org/10.1109/CDC.2016.7798966).
- [30] C. Laughman, S. Nabi, and P. Grover, “A numerical study of refrigerant dispersion in single and multiple connected spaces,” in *ASHRAE Transactions*, vol. 122, 2016.
- [31] V. Vikas, P. Grover, and B. Trimmer, “Model-free control framework for multi-limb soft robots,” in *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, IEEE, 2015, pp. 1111–1116. DOI: [10.1109/IROS.2015.7353509](https://doi.org/10.1109/IROS.2015.7353509).

### Conference Presentations

- [32] P. Grover, M. Huo†, and K. Bakshi†, “Bifurcations in collective decision making within the mean field games framework,” *SIAM Conference on Applications of Dynamical Systems*, 2021.
- [33] —, “Inverse design of collective dynamics in large-scale multi-agent systems via bifurcation analysis of mean field games,” *Second international Nonlinear Dynamics Conference (NODYCON)*, 2021.
- [34] M. Norton, P. Grover, A. Baskaran, M. Hagan, and S. Fraden, “Switching between coherent flow structures in an active nematic fluid using optimal control,” *SIAM Conference on Applications of Dynamical Systems*, 2021.
- [35] C. Wagner\*\*, M. Norton, J. S. Park, and P. Grover, “Bifurcations and the nature of transition to turbulence in active nematic channel flow,” *American Physical Society, March Meeting*, 2021.
- [36] —, “Exploring the phase space of active nematics via exact coherent structures,” *Active matter workshop, Telluride Science Research Center*, 2021.
- [37] M. Norton, P. Grover, A. Baskaran, M. Hagan, and S. Fraden, “Spatiotemporal optimal control of an extensile active nematic suspension,” *American Physical Society, 32nd Annual meeting*, 2020.
- [38] P. Grover, K. Bakshi†, and E. Theodorou, “Understanding and designing emergent behavior via stability analysis of mean field games,” *SIAM Conference on Applications of Dynamical Systems*, 2019.
- [39] S. Nabi, P. Grover, and C. Caulfield, “One-shot methods for nonlinear optimization of turbulent flows with heat transfer,” *American Physical Society, 72th Annual DFD meeting*, 2019.
- [40] S. Vijayshankar†, P. Grover, and S. Nabi, “Reduced-order modeling and estimation for buoyancy-driven flow control,” *American Physical Society, 72th Annual DFD meeting*, 2019.
- [41] U. Kalabic, A. Weiss, and P. Grover, “Low-thrust GTO-to-GEO Trajectory optimization and tracking,” *AIAA/AAS Astrodynamics Conference*, 2018.
- [42] P. Grover and K. Elamvazhuthi†, “Perron-Frobenius meet Monge-Kantorovich: A set-oriented graph-based approach to optimal transport,” *SIAM Conference on Applications of Dynamical Systems*, 2017.

- [43] P. Hassanzadeh, P. Grover, and S. Nabi\*, “Reduced-Order Modeling of 3D Rayleigh-Benard Turbulent Convection,” *American Physical Society, 70th Annual DFD meeting*, 2017.
- [44] S. Nabi\*, P. Grover, and C. P. Caulfield, “Nonlinear optimal control policies for buoyancy-driven flows in the built environment,” *American Physical Society, 70th Annual DFD meeting*, 2017.
- [45] —, “Nonlinear optimization of buoyancy-driven ventilation flow,” *American Physical Society, 69th Annual DFD meeting*, 2016.
- [46] P. Grover, B. Kramer†, P. Boufounos, S. Nabi\*, and M. Benosman, “Sparse sensing based detection of dynamical phenomena and flow transitions,” *SIAM Conference on Applications of Dynamical Systems*, 2015.
- [47] P. Grover and S. Nabi, “Near-optimal source placement in forced convection,” *American Physical Society, 68th Annual DFD meeting*, 2015.
- [48] P. Grover and Y. Song†, “Optimal transport of diffusive scalar from the boundary,” *American Physical Society, 67th Annual DFD meeting*, 2014.
- [49] S. Naik† and P. Grover, “Thermal coherent sets and heat transfer in chaotic laminar flows,” *American Physical Society, 66th Annual DFD meeting*, 2013.
- [50] P. Grover, “Topological chaos and braiding of almost-cyclic sets,” *9th International Conference on Flow Dynamics (ICFD), Sendai, Japan*, 2012.
- [51] P. Grover and C. Andersson†, “Optimized Three-Body Gravity Assists and Manifold Transfers in End-to-End Lunar Mission Design,” *22nd AAS/AIAA Space Flight Mechanics Meeting*, 2012.
- [52] P. Grover and Y. Sato, “Efficient estimation and uncertainty quantification in space mission dynamics,” *AIAA/AAS Astrodynamics Conference*, 2012.
- [53] Y. Sato, P. Grover, and S. Yoshikawa, “Probability Representation of Spacecraft Orbit Error for Robust Trajectory Design,” *22nd JAXA Workshop on Astrodynamics and Flight Mechanics*, 2012.
- [54] P. Grover, S. Ross, M. Stremmler, and P. Kumar, “Characterizing changes in topological entropy via break-up of almost-invariant sets,” *American Physical Society, 63rd Annual DFD meeting*, 2010.
- [55] M. Stremmler, S. Ross, P. Grover, and P. Kumar, “Almost-invariant sets as “ghost rods” for fluid stirring,” *American Physical Society, 63rd Annual DFD meeting*, 2010.
- [56] P. Grover and S. Ross, “Noise Induced Chaos and Calculation of Noisy Lyapunov Exponent in Complex Systems,” *SIAM Conference on Applications of Dynamical Systems*, 2009.
- [57] —, “Designing trajectories in a Planet-Moon environment using a controlled Keplerian Map,” *AAS/AIAA Space Flight Mechanics Meeting*, 2008.
- [58] S. Ross and P. Grover, “Fuel-optimal trajectories in a planet-moon environment using multiple gravity assists,” *20th International Symposium on Space Flight Dynamics (ISSFD)*, 2007.

## Patents

- [59] M. Benosman, P. Boufounos, B. Kramer, and P. Grover, “System and method for controlling operations of air-conditioning system,” pat., US Patent 9,976,765, 2018.
- [60] A.-m. Farahmand, S. Nabi, P. Grover, and D. N. Nikovski, “Method for data-driven learning-based control of HVAC systems using high-dimensional sensory observations,” pat., US Patent Application 15,290,038, 2018.

- [61] P. Grover and K. Elamvazhuthi, “Multi-agent control system and method,” pat., US Patent Application 15,340,015, 2018.
- [62] P. Grover, “System and method for estimating states of spacecraft in planet-moon environment,” pat., US Patent 9,114,893, 2015.
- [63] P. Grover and C. Andersson, “System and method for controlling motion of spacecrafts,” pat., US Patent 8,655,589, 2014.

## Research Supervision

### **Postdoctoral researchers**

- Caleb Wagner (Ph.D., Brandeis U.): Fall 2020-Present

### **Ph.D. students**

- Mohammed A. Mohammed: Fall 2020-Present
- Ali Akbar Rezaei: Summer 2021-Present

### **Dissertation Committee**

- Ethan Davis, University of Nebraska-Lincoln, Graduated 2021
- Kaivalya Bakshi, Aerospace Engineering, Georgia Tech, Graduated 2018

### **Ph.D. student interns supervised at MERL**

Mandy Huo (2019, Caltech), Francisco Gonzales (2018, UIUC), Mithu Debnath (2018, U. Texas at Dallas), Kaivalya Bakshi (2017-18, Georgia Tech), Karthik Elamvazhuthi (2016, Arizona State Univ), Peter Mueller (2015, Wisconsin-Madison), Boris Kramer (2014, Virginia Tech), Yunfei Song (2014, Lehigh U.), Astitva Tripathi (2014, Purdue U.), Saleh Nabi (2013, U. Alberta), Shibabrat Naik (2013, Virginia Tech), Ashuman Mishra (2012, UIUC), Guanqing Xue (2011, Purdue U.), Christian Andersson (2011, Lund U., Sweden)

## Service

Proposal Review: NSF CMMI (2021-Present), SACNAS (2021-Present)

Journal Review: *Journal of Nonlinear Science*, *SIAM Journal of Applied Dynamical Systems*, *Philosophical Transactions of the Royal Society A*, *Communications in Nonlinear Science and Numerical Simulation*, *Celestial Mechanics and Dynamical Astronomy*, *IEEE Control Systems Letters*, *AIAA Journal of Guidance, Control and Dynamics*, *ASME Journal of Computational and Nonlinear Dynamics*, *Journal of Astronautical Sciences*, *ASME Journal of Dynamic systems, measurement and control*, *Journal of Physics A: Mathematical and Theoretical*

Conference Review: *Control and Decision Conference (CDC)*, *American Control Conference (ACC)*, *Conference on Neural Information Processing Systems (NEURIPS)*, *ASME Dynamic Systems and Control Conference (DSCC)*, *Hybrid Systems: Computation and Control Conference (HSCC)*

Conference Organization : USNCTAM-2022 Minisymposium on Nonlinear Dynamics of Active Fluids

## Teaching

### **At UNL**

Fall 2019, 2020, 2021	Mechanical Engineering Control Systems Design (48 Students, 26 students, 22 Students)
Summer 2020	Special Topics - Intro to Dynamical Systems and Chaos (12 Students)
Spring 2021	Advanced Dynamics (14 Students)
Spring 2021	Special Topics- Data driven science and engineering (Co-instructor, 24 Students)

### Workshop Attendance

Particulate and Granular Networks (Max Planck Institute, Dresden, Germany July 2019), Crowds: Models and Control Workshop (CIRM, France June 2019), IPAM workshop on mean field games (UCLA, 2017), IMA workshop on Computational Methods for Control of Infinite-dimensional Systems (Univ. Minnesota, 2016), Summer school on Transport, Fluids and Mixing (Univ. Trento, Italy, 2015), CRM workshop on Planetary Motions, Satellite Dynamics, and Spaceship Orbits (Univ. Montreal, Canada, 2013), IMA workshop on Algebraic Topology in Dynamics, Differential Equations, and Experimental Data (Univ. Minnesota, 2013), Workshop on Coherent Structures in Dynamical Systems (Univ. Lieden, Netherlands, 2011)