Sungho Shin

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Education

University of Wisconsin-Madison, Madison, WI 2021
Ph.D. in Chemical Engineering
Minor in Industrial Engineering
Thesis: *Graph-Structured Nonlinear Programming: Properties and Algorithms*
Thesis Advisor: Victor M. Zavala

Seoul National University, Seoul, South Korea 2016
B.S. in Chemical Engineering
B.S. in Mathematics
Thesis Advisors: Jong Min Lee (Chemical Engineering) and Seng Yeal Ha (Mathematics)
Summa cum Laude

Research Interests

control theory; model predictive control; nonlinear optimization; stochastic optimization; energy systems

Research Experience

Postdoctoral Appointee 2021 – Present
Argonne National Laboratory, Lemont, IL
Mathematics and Computer Science Division
Supervisor: Mihai Anitescu

- Proved the *near-optimality* of two widely used control techniques—*distributed control* and *stochastic model predictive control*
- Collaborated with Exascale Computing Project team to develop optimization algorithms and software tools for solving large-scale optimization problems using GPU/SIMD architecture
- Mentored several Ph.D. students during their summer internships performing research, developing software packages, and writing papers and technical reports
- Initiated an external research collaboration on distributed control (with Prof. Adam Wierman at Caltech and Prof. Guannan Qu at Carnegie Mellon University)
- Contributed to two grant proposals (one funded) by writing several sections and developing core idea with PIs

Research Assistant 2016 – 2021
University of Wisconsin-Madison, Madison, WI
Department of Chemical and Biological Engineering
Supervisor: Victor M. Zavala

- Led the study of *graph-structured optimization*, a generalized abstraction of diverse optimization problems
- Established *exponential decay of sensitivity*, a fundamental property of graph-structured optimization, which enables the creation of scalable algorithms
- Established the convergence property of the *overlapping Schwarz method*, a novel decomposition paradigm for graph-structured optimization; demonstrated its effectiveness with energy system optimization problems

Research Intern 2020
Los Alamos National Laboratory, Los Alamos, NM
Advanced Network Science Initiative
Supervisor: Carleton Coffrin and Kaarthik Sundar

- Developed a nonlinear optimization solver MadNLP.jl that facilitates applying scalable linear algebra techniques
- Demonstrated the scalability of MadNLP.jl with large-scale power and gas network optimization problems

Research Intern 2018
Argonne National Laboratory, Lemont, IL
Mathematics and Computer Science Division
Supervisor: Mihai Anitescu

- Developed a new decomposition paradigm for large-scale optimization and analyzed its convergence property
- Implemented the decomposition algorithm using MPI and tested its performance using the clusters at Argonne

Research Intern 2016
Seoul National University, Seoul, South Korea
Department of Chemical and Biological Engineering
Supervisor: Jong Min Lee.

- Collaborated with industry to develop process models based on the process flowsheet
- Developed a machine learning technique to detect fouling in water networks using pressure data

Honors and Awards

Honors

Young Author Award, IFAC Conference on Nonlinear Model Predictive Control 2021

- Paper Title: *Controllability and Observability Imply Exponential Decay of Sensitivity in Dynamic Optimization*
- Awarded to the best paper of which the first and presenting author has Ph.D.-student status at the time of paper submission and is the main contributor of the research results in the paper

Young Author Award, IFAC International Symposium on Advanced Control of Chemical Processes 2021

- Paper Title: *Graph-Based Modeling and Decomposition of Energy Infrastructures*
- Awarded to the best paper of which the first and presenting author has the Ph.D.-student status at the time of paper submission and is the main contributor of the research results in the paper

CAST Directors' Student Presentation Award, AIChE 2020

- Paper Title: *Overlapping Schwarz: A New Decomposition Paradigm for Large-Scale Optimization*
- Awarded to the student who delivered the best presentation, among eight students selected as finalists to present a research paper at the AIChE Annual Meeting, judged by the CAST Directors and executive committee.

Fellowships and Scholarships

Grainger Wisconsin Distinguished Graduate Fellowship, University of Wisconsin-Madison 2020 – 2021

- Awarded to the distinguished graduate student with dissertator status

Kwanjeong Scholarship, Kwanjeong Educational Foundation 2016 – 2020

- Awarded to outstanding Korean students who have gained admission to widely recognized universities

Korea Presidential Science Scholarship, Korea Student Aid Foundation 2010 – 2016

- Prestigious merit-based scholarship the aim of which is to select and support top talents with great creativity and potential in the fields of science and technology

Travel Awards

IEEE Conference on Decisions and Control 2020
Wisconsin Student Research Grants Competition 2019
Machine Learning for Science and Engineering 2019

Mentoring Experience

Argonne National Laboratory, Lemont, IL

Miao Li (Predoctoral Appointee) Fall 2022 – Present
- Project: *Policy optimization for sequential decision-making under uncertainty*
- Co-advised with Mihai Anitescu and Kibaek Kim

Anthony Spyros Degleris (Stanford University) Summer 2022
- Project: *Iterative Newton methods on GPU for solving optimal power flow problems*
- Co-advised with Michel Schanen and Francois Pacaud

David Cole (University of Wisconsin-Madison) Summer 2022
- Project: *Exploiting GPU/SIMD architectures for solving linear-quadratic MPC problems*
- Co-advised with Francois Pacaud

Rishabh Gupta (University of Minnesota) Spring 2022
- Project: *Implementation of a decomposition solver for structured nonlinear programs*
- Co-advised with Anirudh Subramanyam and Francois Pacaud

University of Wisconsin-Madison, Madison, WI

Sang-il Kwon (University of Wisconsin-Madison) Fall 2017
- Project: *Parameter Estimation for Biological System Models*

Teaching Experience

University of Wisconsin-Madison, Madison, WI

Statistics for Chemical Engineers, Teaching Assistant Spring 2019
- An elective statistics course for senior chemical engineering major students
- Held office hours; developed homework problems

Process Dynamics and Control, Teaching Assistant Fall 2018, Fall 2017
- A required control course for senior chemical engineering major students
- Instructed lab sessions (10-15 students); supervised experiments and simulations; revised/improved lab manual
- Instructed discussion sessions (50–60 students); held office hours; graded homework, lab reports, and exams

Seoul National University, Seoul, South Korea

Process Control and Design, Undergraduate Tutor Fall 2015
- Held office hours

Process Fluid Mechanics, Undergraduate Tutor Spring 2015
- Held office hours

Basic Chemistry, Undergraduate Tutor Spring 2015
- Held office hours

Professional Services

Academic Services

Session Chair INFORMS Annual Meeting (expected) 2022

Session Co-Chair AIChE Annual Meeting (expected) 2022

Reviewer AIChE Annual Meeting CAST Division (10B, 10E) 2022

Co-Chair, Summer Argonne Students Symposium, 2022

Judge, Research Presentation Sessions, Argonne Postdoctoral Research and Career Symposium 2021

Peer Review

Proposals: NSF

Journals: AIChE Journal; IEEE Transactions on Automatic Control; Automatica; Computers & Chemical Engineering; IEEE Control Systems Letters; IEEE Transactions on Control Systems Technology; Industrial & Engineering Chemistry Research; Journal of Optimization Theory and Applications; SIAM Journal on Optimization

Conferences: American Control Conference; IFAC Conference on Nonlinear Model Predictive Control; IFAC International Symposium on Advanced Control of Chemical Processes

Outreach and Others

SCIENCountErs, University of Wisconsin-Madison Fall 2018

- Instructed science activities for students at Boys and Girls Club of Dane County
- Aims to help build a pipeline of STEM students from underrepresented groups

Various Roles, Graduate Recruiting Events, University of Wisconsin-Madison 2018–2021

- Participated in graduate recruitment events multiple times as host, driver, and poster presenter
- Created department collaboration graph, used for department introduction presentations
- Ran and maintained the scheduling software for the faculty-prospective student meeting

Professional Affiliations

- **American Institute of Chemical Engineers** (AIChE)
- **Institute of Electrical and Electronics Engineers** (IEEE) — Control Systems Society
- **Institute for Operations Research and the Management Sciences** (INFORMS)
- **Society for Industrial and Applied Mathematics** (SIAM)

Publications

In Preparation

[P2] **S. Shin** and M. Anitescu. Improved perturbation bounds for graph-induced banded systems and application to optimal control. In Preparation.

[P1] **S. Shin**, S. Na, and M. Anitescu. Near-optimal performance of stochastic predictive control. arXiv:2210.08599. In Preparation.

Under Review

[U2] D. Cole, **S. Shin**, F. Pacaud, V. M. Zavala, and M. Anitescu. Exploiting GPU/SIMD architectures for solving linear-quadratic MPC problems. arXiv:2209.13049. Under Review at *Annual American Control Conference*.

[U1] **S. Shin**, F. Pacaud, E. Constanteniscu, and M. Anitescu. Constrained policy optimization for stochastic optimal control under nonstationary uncertainties. arXiv:2209.13050. Under Review at *Annual American Control Conference*.

Journal Publications

[J12] **S. Shin**, Y. Lin, G. Qu, A. Wierman, and M. Anitescu. Near-optimal distributed linear-quadratic regulator for networked systems. *SIAM Journal on Control and Optimization*, 2022, arXiv:2204.05551. Accepted.

[J11] F. Pacaud, **S. Shin**, M. Schanen, D. A. Maldonado, and M. Anitescu. Condensed interior-point methods: porting reduced-space approaches on GPU hardware. *Journal of Optimization Theory and Applications*, 2022, arXiv:2203.11875. Accepted.

[J10] F. Pacaud, D. A. Maldonado, **S. Shin**, M. Schanen, and M. Anitescu. A feasible reduced space method for real-time optimal power flow. *Electric Power Systems Research*, 212:108268, 2022, arXiv:2110.02590. doi:10.1016/j.epsr.2022.108268.

[J9] D. L. Cole, **S. Shin**, and V. M. Zavala. A julia framework for graph-structured nonlinear optimization. *Industrial & Engineering Chemistry Research*, 2022, arXiv:2204.05264. doi:10.1021/acs.iecr.2c01253.

[J8] S. Na*, **S. Shin***, M. Anitescu, and V. M. Zavala. On the convergence of overlapping schwarz decomposition for nonlinear optimal control. *IEEE Transactions on Automatic Control*, 2022, arXiv:2005.06674. doi:10.1109/TAC.2022.3194087. *Equal contribution.

[J7] J. Jalving, **S. Shin**, and V. M. Zavala. A graph-based modeling abstraction for optimization: Concepts and implementation in Plasmo.jl. *Mathematical Programming Computation*, 2022, arXiv:2006.05378. doi:10.1007/s12532-022-00223-3.

[J6] **S. Shin**, M. Anitescu, and V. M. Zavala. Exponential decay of sensitivity in graph-structured nonlinear programs. *SIAM Journal on Optimization*, 32(2):1156–1183, 2022, arXiv:2101.03067. doi:10.1137/21M1391079.

[J5] **S. Shin** and V. M. Zavala. Diffusing-horizon model predictive control. *IEEE Transactions on Automatic Control*, 2022, arXiv:2002.08556. doi:10.1109/TAC.2021.3137100.

[J4] **S. Shin**, V. M. Zavala, and M. Anitescu. Decentralized schemes with overlap for solving graph-structured optimization problems. *IEEE Transactions on Control of Network Systems*, 7(3):1225–1236, 2020, arXiv:1810.00491. doi:10.1109/TCNS.2020.2967805.

[J3] **S. Shin**, P. Hart, T. Jahns, and V. M. Zavala. A hierarchical optimization architecture for large-scale power networks. *IEEE Transactions on Control of Network Systems*, 6(3):1004–1014, 2019, arXiv:2002.09796. doi:10.1109/TCNS.2019.2906917.

[J2] **S. Shin**, O. S. Venturelli, and V. M. Zavala. Scalable nonlinear programming framework for parameter estimation in dynamic biological system models. *PLoS Computational Biology*, 15(3):e1006828, 2019. doi:10.1371/journal.pcbi.1006828.

[J1] D. S. Kim, **S. Shin**, G. B. Choi, K. H. Jang, J. C. Suh, and J. M. Lee. Diagnosis of partial blockage in water pipeline using support vector machine with fault-characteristic peaks in frequency domain. *Canadian Journal of Civil Engineering*, 44(9):707–714, 2017. doi:10.1139/cjce-2016-0615.

Conference Publications

[C6] **S. Shin** and V. M. Zavala. Controllability and observability imply exponential decay of sensitivity in dynamic optimization. In *7th IFAC Conference on Nonlinear Model Predictive Control*, volume 54, pages 179–184, 2021, arXiv:2101.06350. doi:10.1016/j.ifacol.2021.08.542. Young Author Award.

[C5] **S. Shin**, C. Coffrin, K. Sundar, and V. M. Zavala. Graph-based modeling and decomposition of energy infrastructures. In *11th IFAC International Symposium on Advanced Control of Chemical Processes*, volume 54, pages 693–698, 2021, arXiv:2010.02404. doi:10.1016/j.ifacol.2021.08.322. Keynote Paper, Young Author Award.

[C4] **S. Shin**, M. Anitescu, and V. M. Zavala. Overlapping Schwarz decomposition for constrained quadratic programs. In *2020 59th IEEE Conference on Decision and Control (CDC)*, pages 3004–3009, 2020, arXiv:2003.07502. doi:10.1109/CDC42340.2020.9304139.

[C3] Q. Lu, **S. Shin**, and V. M. Zavala. Characterizing the predictive accuracy of dynamic mode decomposition for data-driven control. In *21th IFAC World Congress*, volume 53, pages 11289–11294, 2020, arXiv:2003.01028. doi:https://doi.org/10.1016/j.ifacol.2020.12.373.

[C2] **S. Shin**, T. Faulwasser, M. Zanon, and V. M. Zavala. A parallel decomposition scheme for solving long-horizon optimal control problems. In *2019 IEEE 58th Conference on Decision and Control (CDC)*, pages 5264–5271, 2019, arXiv:1903.01055. doi:10.1109/CDC40024.2019.9030139.

[C1] **S. Shin**, A. D. Smith, S. J. Qin, and V. M. Zavala. On the convergence of the dynamic inner PCA algorithm. In *Foundations of Process Analytics and Machine Learning*, 2019, arXiv:2003.05928.

Book Chapters, Technical Reports, and Others

[B5] M. Anitescu, K. Kim, Y. Kim, A. Maldonado, F. Pacaud, V. Rao, M. Schanen, **S. Shin**, and A. Subramanian. Targeting Exascale with Julia on GPUs for multiperiod optimization with scenario constraints. *SIAG/OPT Views and News*, 2021. URL http://wiki.siam.org/siag-op/images/siag-op/e/e8/ViewsAndNews-29-1.pdf.

[B4] P. F. Lang, **S. Shin**, and V. M. Zavala. SBML2Julia: interfacing SBML with efficient nonlinear Julia modeling and solution tools for parameter optimization. 2020, arXiv:2011.02597.

[B3] **S. Shin**, Q. Lu, and V. M. Zavala. Unifying theorems for subspace identification and dynamic mode decomposition. 2020, arXiv:2003.07410.

[B2] **S. Shin** and V. M. Zavala. Computing economic-optimal and stable equilibria for droop-controlled microgrids. 2018, arXiv:2002.09802.

[B1] **S. Shin** and V. M. Zavala. Multi-grid schemes for multi-scale coordination of energy systems. In *Energy Markets and Responsive Grids*, pages 195–222. Springer, 2018, arXiv:2002.10680. doi:10.1007/978-1-4939-7822-9_9.

Dissertations

[D1] **S. Shin**. *Graph-Structured Nonlinear Programming: Properties and Algorithms*. The University of Wisconsin-Madison, 2021. URL https://www.proquest.com/docview/2544907352.

Presentations

Invited Talks

[I5] Scalable decision-making for energy infrastructures: Theory, algorithms, and software. Young Researcher Symposium, Seoul National University, 2022.

[I4] Graph-structured nonlinear programming: Properties and algorithms. ALOP colloquium, Trier University, 2021.

[I3] Graph-structured nonlinear programming: Properties and algorithms. Rigorous Systems Research Group, Caltech, 2021.

[I2] Graph-structured optimization for energy infrastructures. Department of Chemical and Biological Engineering Seminar, University of Wisconsin-Madison, 2021.

[I1] Exponential decay of sensitivity in graph-structured nonlinear programs. University of Bayreuth, 2020.

Conference Talks

[T18] Near-optimal performance of stochastic predictive control. INFORMS Annual Meeting, Indianapolis, IN, 2022 (expected).

[T17] On the performance of stochastic predictive control. AIChE Annual Meeting, Phoenix, AZ 2022 (expected).

[T16] Near-optimal distributed linear-quadratic regulator for networked systems. AIChE Annual Meeting, Phoenix, AZ 2022 (expected).

[T15] Graph-structured nonlinear programming: Properties and algorithms. 7th International Conference on Continuous Optimization, Bethlehem, PA, 2022.

[T14] MadNLP.jl: A mad nonlinear programming solver. JuliaCon 2021.

[T13] Controllability and observability imply exponential decay of sensitivity in dynamic optimization. 7th IFAC Conference on Nonlinear Model Predictive Control, 2021.

[T12] Graph-based modeling and decomposition of energy infrastructures. 11th IFAC International Symposium on Advanced Control of Chemical Processes, 2021.

[T11] Overlapping schwarz decomposition for constrained quadratic programs. 58th IEEE Conference on Decision and control, 2020.

[T10] Unifying theorems for unifying theorems for subspace identification and dynamic mode decomposition. AIChE Annual Meeting, 2020.

[T9] Diffusing-horizon model predictive control. AIChE Annual Meeting, 2020.

[T8] Overlapping domain decomposition schemes for solving graph-structured optimization problems. AIChE Annual Meeting, 2020.

[T7] A parallel decomposition scheme for solving long-horizon optimal control problems. 58th IEEE Conference on Decision and control, Nice, France, 2019.

[T6] Overlapping domain decomposition schemes for solving graph-structured optimization problems. AIChE Annual Meeting, Orlando, FL, 2019.

[T5] Low-rank system identification from high-dimensional data. Computing in Engineering Forum, Madison, WI, 2019.

[T4] Optimization algorithms for dynamic latent variable problems. MLSE, Atlanta, GA, 2019.

[T3] Stability-preserving economic optimization of microgrids. AIChE Annual Meeting, Pittsburgh, PA, 2018.

[T2] Multi-grid (hierarchical) control of power networks. AIChE Annual Meeting, Minneapolis, MN, 2017.

[T1] Large-scale estimation techniques for dynamic microbial community networks. TWCCC Fall Meeting, Madison, WI, 2017.

Software Products

[S1] **MadNLP.jl** (Main developer)
- a nonlinear programming solver
- allows for exploiting problem structures via abstract KKT system feature
- allows for solving dense nonlinear optimization problems on GPU efficiently
- https://github.com/MadNLP/MadNLP.jl

[S2] **Plasmo.jl** (Contributor)
- a graph-based algebraic modeling framework
- https://github.com/plasmo-dev/Plasmo.jl

[S3] **MadDiff.jl** (Main developer)
- a sparse automatic differentiation and algebraic modeling tool
- https://github.com/sshin23/MadDiff.jl

[S4] **DynamicNLPModels.jl** (Contributor)
- a GPU-friendly modeling tool for dynamic optimization problems
- https://github.com/MadNLP/DynamicNLPModels.jl

[S5] **BlockNLPModels.jl** (Contributor)
- a data structure for block nonlinear programming models
- https://github.com/exanauts/BlockNLPModels.jl

[S6] **BlockNLPAlgorithms.jl** (Contributor)
- a decomposition solver for BlockNLPModels
- https://github.com/exanauts/BlockNLPAlgorithms.jl

[S7] **SBML2Julia** (Contributor)
- a tool for estimating parameters of biological system models in SBML format
- https://github.com/paulflang/SBML2Julia