Joshua Pulsipher, Ph.D.

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pulsipher
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Degrees

2017 – 2022 **Ph.D. in Chemical & Biological Engineering**
University of Wisconsin-Madison (Madison, WI)
Advisor: Prof. Victor M. Zavala
Thesis: Infinite-Dimensional Optimization: Modeling Abstractions and Software

2012 – 2017 **B.Sc. in Chemical Engineering**
Brigham Young University (Provo, UT)
Advisor: Prof. John D. Hedengren
Focus: Process Systems Engineering & UAV-Based Infrastructure Monitoring

Relevant Employment History

Research

2022 – Present **Post-Doctoral Associate**
Chemical Engineering, Carnegie Mellon University (Pittsburgh, PA)
Advisors: Profs. Carl D. Laird and Ignacio E. Grossmann
Areas: Data-Driven Decision-Making, Rare Earth Elements, Disease Control, Process Systems

2017 – 2022 **Graduate Research Assistant**
Chemical & Biological Engineering, University of Wisconsin-Madison (Madison, WI)
Areas: Decision-Making under Uncertainty, Advanced Control, Energy Systems, Data-Science

2020 **Applications Engineering Research Intern**
Differentiating Technologies, ExxonMobil Research & Engineering (Spring, TX)
Developed cognitive computer vision sensing framework (patent pending)

2019 **Research Intern**
Optimization & Control, Pacific Northwest National Laboratory (Richland, WA)
Innovated uncertainty propagation analysis for power grid operation

2013 – 2017 **Undergraduate Research Assistant**
Chemical Engineering, Brigham Young University (Provo, UT)
Co-founded optimal UAV-based infrastructure monitoring research program

Teaching

2019 **Recitation Leader**
Chemical & Biological Engineering, University of Wisconsin-Madison (Madison, WI)
Course: Introduction to Chemical Process Modeling
Instructed 1/3 of main lectures with new programming curriculum; obtained 94% approval rating

2018 **Teaching Assistant**
Chemical & Biological Engineering, University of Wisconsin-Madison (Madison, WI)
Course: Process Dynamics & Control
Helped overhaul the control laboratory structure and curriculum

2013 **Recitation Leader**
Chemistry, Brigham Young University (Provo, UT)
Course: Organic Chemistry 1
Achieved 1st quantile grades among all sections taught

Funding Proposals

2023 *NSF IRES Track II: Pan-American Advanced Studies Institute on Data Science and Optimization for Net–Zero Carbon and Sustainability*, U.S. National Science Foundation, **$134K**, *Under Review*, Role: Senior Personnel & Organizing Committee Member (contributed to workshop design and proposal preparation)

2022 – 2023 *Multi-Enterprise REE/CM Network Optimization*, U.S. Department of Energy (subcontracted via KeyLogic Systems, Inc.), **$550K**, Role: Senior Personnel (contributed to writing and scoping of the project proposal)

2016 – 2017 *Optimal UAV-Based Infrastructure Monitoring*, U.S. National Science Foundation, **$14K**, Role: Undergraduate Recipient (scoped and wrote the proposal for funding)

Honors and Awards

- **Travel Award**, Foundations of Computer Aided Process Operations / Chemical Process Control (2023)
- **Plenary Speaker**, Computing & Systems Technology Division Plenary Session of the AICHE Annual Meeting (2022)
- **Undergraduate Research Fellowship**, National Science Foundation (2016)
- **Full Academic Scholarship**, Brigham Young University (2013 – 2017)
- **Academic Scholarship**, Brigham Young University Chemical Engineering Department (2012)
- **Masonic Academic Achievement Scholarship**, Yakima Masonic Lodge (2012)
- **Eagle Scout**, Boy Scouts of America (2012)
- **President's List**, Yakima Valley Community College (2011 – 2012)

Research Publications

Journal Articles

12 Ammari, B. L., Bynum, M., Johnson, E. S., **Pulsipher**, **J. L.**, Hart, W. E., and Laird, C. D. (2022). "Comparison of Mixed-Integer Characterizations for Linear Tree Surrogates Embedded in Optimization Problems". *In Preparation*.

11 Ammari, B. L., Merakli, M., Kompalli, S., Qian, Y., **Pulsipher**, **J. L.**, Bynum, M., Furman, K. C., and Laird, C. D. (2022). "Computational Performance of Algebraic Modeling Languages with Alternate Solver Interfaces and Advanced Modeling Components". *In Preparation*.

10 **Pulsipher**, **J. L.**, Cummings, D. A. T., and Laird, C. D. (2022). "Computationally Efficient Global Optimization Approaches for Estimation of Transmission Parameter Profiles in Infectious Disease Models". *In Preparation*.

9 **Pulsipher**, **J. L.**, Ovalle, D., Perez, H. D., Laird, C. D., and Grossmann, I. E. (2022). "Characterizing Event Constraints with Generalized Disjunctive Programming". *In Preparation*.

8 **Pulsipher**, **J. L.**, Coutinho, L. D., Soderstrom, T. A., and Zavala, V. M. (Aug. 2022). "SAFE-OCC: A Novelty Detection Framework for Convolutional Neural Network Sensors and its Application in Process Control". In: *Journal of Process Control* 117, pp. 78–97. URL: https://doi.org/10.1016/j.jprocont.2022.07.006.

7 **Pulsipher**, **J. L.**, Davidson, B. R., and Zavala, V. M. (Aug. 2022). "Random Field Optimization". In: *Computers & Chemical Engineering* 165. URL: https://doi.org/10.1016/j.compchemeng.2022.107854.

6 **Pulsipher**, **J. L.**, Zhang, W., Hongisto, T. J., and Zavala, V. M. (Jan. 2022). "A unifying modeling abstraction for infinite-dimensional optimization". In: *Computers & Chemical Engineering* 156. URL: https://doi.org/10.1016/j.compchemeng.2021.107567.

5. **Pulsipher**, **J. L.** and Zavala, V. M. (Feb. 2020). "Measuring and optimizing system reliability: a stochastic programming approach". In: *Top* 28.3, pp. 626–645. URL: https://doi.org/10.1007/s11750-020-00550-5.

4. **Pulsipher**, **J. L.** and Zavala, V. M. (Sept. 2019). "A scalable stochastic programming approach for the design of flexible systems". In: *Computers & Chemical Engineering* 128, pp. 69–76. URL: https://doi.org/10.1016/j.compchemeng.2019.05.033.

3. **Pulsipher**, **J. L.**, Rios, D., and Zavala, V. M. (July 2019). "A computational framework for quantifying and analyzing system flexibility". In: *Computers & Chemical Engineering* 126, pp. 342–355. URL: https://doi.org/10.1016/j.compchemeng.2019.04.024.

2. **Pulsipher**, **J. L.** and Zavala, V. M. (Nov. 2018). "A mixed-integer conic programming formulation for computing the flexibility index under multivariate gaussian uncertainty". In: *Computers & Chemical Engineering* 119, pp. 302–308. URL: https://doi.org/10.1016/j.compchemeng.2018.09.005.

1. Martin, R. A., Blackburn, L., **Pulsipher**, **J. L.**, Franke, K., and Hedengren, J. D. (May 2017). "Potential benefits of combining anomaly detection with view planning for UAV infrastructure modeling". In: *Remote Sensing* 9.5, p. 434. URL: https://doi.org/10.3390/rs9050434.

Dissertations

1. **Pulsipher**, **J. L.** (Feb. 2022). "Infinite-Dimensional Optimization: Modeling Abstractions and Software". PhD thesis. University of Wisconsin-Madison.

Conference Proceedings (Peer Reviewed)

5. Ammari, B. L., Stinchfield, G., Bynum, M., Johnson, E. S., **Pulsipher**, **J. L.**, Qian, Y., Hart, W. E., and Laird, C. D. (Sept. 2022). "Computational Performance of Piecewise Linear Machine Learning Surrogates Embedded in Optimization Problems". *33rd European Symposium on Computer Aided Process Engineering. Accepted for Further Review*.

4. Ovalle, D., **Pulsipher**, **J. L.**, Gomez, C., Gomez, J. M., Laird, C. D., Drouven, M., and Grossmann, I. E. (Sept. 2022). "Study of Different Formulations for the Multiperiod Blending Problem Applied to Lithium Recovery from Produced Water". *33rd European Symposium on Computer Aided Process Engineering. Accepted for Further Review*.

3. Ammari, B. L., Meraklı, M., Kompalli, S., Qian, Y., **Pulsipher**, **J. L.**, Bynum, M., Furman, K. C., and Laird, C. D. (July 2022). "Computational Performance of Algebraic Modeling Languages with Alternate Solver Interfaces and Advanced Modeling Components". *Foundations of Computer Aided Process Operations / Chemical Process Control 2023. In Press*.

2. **Pulsipher**, **J. L.**, Ovalle, D., Perez, H. D., Laird, C. D., and Grossmann, I. E. (July 2022). "Characterizing Event Constraints with Generalized Disjunctive Programming". *Foundations of Computer Aided Process Operations / Chemical Process Control 2023. In Press*.

1. **Pulsipher**, **J. L.**, Davidson, B. R., and Zavala, V. M. (2022). "New Measures for Shaping Trajectories in Dynamic Optimization". *13th IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems*. Vol. 55. 7. IFAC PapersOnLine, pp. 495–500. URL: https://doi.org/10.1016/j.ifacol.2022.07.492.

Book Chapters

1. Jiang, S., Qin, S., **Pulsipher**, **J. L.**, and Zavala, V. M. (May 2022). "Convoluational Neural Networks: Basic Concepts and Applications in Manufacturing". *Artificial Intelligence in Manufacturing*. Ed. by M. Soroush and R. Braatz. *In Press*. URL: https://doi.org/10.48550/arXiv.2210.07848.

Patents

1. Kadam, J. V., Georgiou, A. T., Sheth, K. R., Li, W., Onel, O., and **Pulsipher**, **J. L.** (Dec. 2020). "Systems and Methods of Monitoring and Controlling an Industrial Process". U.S. Patent Application 17/126151.

Newsletter Articles (Peer Reviewed)

1. **Pulsipher, J. L.** and Zavala, V. M. (Mar. 2022). "InfiniteOpt.jl: A Julia Package for Infinite-Dimensional Optimization". Vol. 17. 1. International Federation of Operational Research Societies. URL: https://www.ifors.org/newsletter/ifors-news-march-2022.pdf.

Software

- **InfiniteOpt.jl:** An Infinite-Dimensional Modeling Framework (Julia)
  Role: Lead Developer
  Source: https://github.com/infiniteopt/InfiniteOpt.jl
- **DisjunctiveProgramming.jl:** A Modeling Framework for Discrete Decision-Making via GDP (Julia)
  Role: Developer
  Source: https://github.com/hdavid16/DisjunctiveProgramming.jl
- **FlexibilityAnalysis.jl:** A Framework for Flexibility Analysis (Julia)
  Role: Lead Developer
  Source: https://github.com/pulsipher/FlexibilityAnalysis.jl
- **compvislab:** A Toolbox for Computer Vision Control (Python)
  Role: Lead Developer
- **Volare:** Optimized Flight Planner for UAV Inspection (Android)
  Role: Developer

Research Presentations

Invited Talks

17. **Pulsipher, J. L.** (Feb. 2023). "Optimization under Uncertainty: From Data to Models to Decision-Making". *University of South Florida Chemical, Biological and Materials Engineering Department Seminar*. Tampa, FL.
16. **Pulsipher, J. L.** (Jan. 2023). "Optimization under Uncertainty: From Data to Models to Decision-Making". *University of Waterloo Chemical Engineering Department Seminar*. Waterloo, Canada.
15. **Pulsipher, J. L.** (Jan. 2023). "Optimization under Uncertainty: From Data to Models to Decision-Making". *Rensselaer Polytechnic Institute Chemical and Biological Engineering Department Seminar*. Troy, NY.
14. **Pulsipher, J. L.** (Jan. 2023). "Optimization under Uncertainty: From Data to Models to Decision-Making". *Brigham Young University Chemical Engineering Department Seminar*. Provo, UT.
13. **Pulsipher, J. L.**, Ovalle, D., Perez, H. D., Laird, C. D., and Grossmann, I. E. (Jan. 2023). "Characterizing Event Constraints with Generalized Disjunctive Programming". *Foundations of Computer Aided Process Operations / Chemical Process Control 2023*. San Antonio, TX.
12. **Pulsipher, J. L.** (Nov. 2022). "An Introduction to Process Systems Engineering with Applications in Energy and Disease Control". *University International Seminar at Universidad Nacional Micaela Bastidas de Apurímac*. Apurímac, Peru.
11. **Pulsipher, J. L.**, Laird, C. D., and Grossmann, I. E. (Nov. 2022). "Event Constrained Optimization". *The American Institute of Chemical Engineering (AICHE) Annual Meeting*. **Computing & Systems Technology Division Plenary**. Phoenix, AZ.
10. **Pulsipher, J. L.** and Laird, C. D. (Oct. 2022). "Advances In Solving Infinite-dimensional Optimization Problems With Infiniteopt.jl". *The Institute for Operations Research and the Management Sciences (INFORMS) Annual Meeting*. Indianapolis, IN.
9. **Pulsipher, J. L.** (Sept. 2022). "Software-Accelerated Theoretical Discovery via InfiniteOpt.jl". *Carnegie Mellon University Process Systems Engineering Seminar*. Pittsburgh, PA.

8. **Pulsipher, J. L.**, Davidson, B. R., and Zavala, V. M. (July 2022). "Random Field Optimization". *International Conference on Continuous Optimization (ICCOPT)*. Bethlehem, PA.
7. **Pulsipher, J. L.**, Coutinho, L., and Zavala, V. M. (June 2022). "Computer Vision Aided Process Control: Methods for Enhanced Autonomy and Robustness". *Advanced Manufacturing & Processing Conference (AMPc)*. Bethesda, MD.
6. **Pulsipher, J. L.** and Laird, C. D. (June 2022). "Data-Driven Surrogates for Infinite-Dimensional Optimization Problems". *CORS/INFORMS International Conference*. Vancouver, Canada.
5. **Pulsipher, J. L.**, Zhang, W., and Zavala, V. M. (Feb. 2021). "InfiniteOpt.jl: A unifying abstraction for Infinite-Dimensional Optimization". *The Institute for Operations Research and the Management Sciences (INFORMS) Annual Meeting*. Anaheim, CA.
4. **Pulsipher, J. L.**, Zhang, W., and Zavala, V. M. (Feb. 2021). "Tackling Infinite-Dimensional Optimization Problems with InfiniteOpt.jl". *Texas-Wisconsin-California Control Consortium (TWCCC) Semi-Annual Meeting*. Online.
3. **Pulsipher, J. L.**, Zhang, W., and Zavala, V. M. (Nov. 2020). "Modeling Infinite-Dimensional Optimization Problems with InfiniteOpt.jl". *The Institute for Operations Research and the Management Sciences (INFORMS) Annual Meeting*. Online.
2. **Pulsipher, J. L.** and Zavala, V. M. (Oct. 2020). "Modeling Infinite-Dimensional Optimization Problems with InfiniteOpt.jl". *UW-Madison Chemical & Biological Engineering Computational Seminar Series*. Madison, WI.
1. **Pulsipher, J. L.** and Zavala, V. M. (Oct. 2019). "Engineering Optimal Systems". *UW-Madison Undergraduate Seminar Series*. Madison, WI.

Other Talks

11. **Pulsipher, J. L.**, Lin, S., Xi, Y., and Laird, C. D. (June 2023). "Computationally Efficient Global Optimization Approaches for the Estimation of Transmission Parameter Profiles in Infectious Disease Models". *33rd European Symposium on Computer Aided Process Engineering*. Athens, Greece.
10. **Pulsipher, J. L.**, Coutinho, L., and Zavala, V. M. (Nov. 2022). "Computer Vision Aided Process Control: Methods for Enhanced Autonomy and Robustness". *The American Institute of Chemical Engineering (AICHE) Annual Meeting*. Phoenix, AZ.
9. **Pulsipher, J. L.**, Davidson, B. R., and Zavala, V. M. (Nov. 2022). "New Measures for Shaping Trajectories in Dynamic Optimization". *The American Institute of Chemical Engineering (AICHE) Annual Meeting*. Phoenix, AZ.
8. **Pulsipher, J. L.** (July 2022). "Advances in Transformations and NLP Modeling for InfiniteOpt.jl". *Julia-Con*. Online.
7. **Pulsipher, J. L.**, Davidson, B. R., and Zavala, V. M. (June 2022). "New Measures for Shaping Trajectories in Dynamic Optimization". *IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems (DYCOPS)*. Busan, South Korea.
6. **Pulsipher, J. L.** and Zavala, V. M. (Nov. 2021). "Random Field Optimization". *The American Institute of Chemical Engineering (AICHE) Annual Meeting*. Boston, MA.
5. **Pulsipher, J. L.**, Zhang, W., and Zavala, V. M. (Nov. 2021). "InfiniteOpt.jl: A Unifying Abstraction for Infinite-Dimensional Optimization". *The American Institute of Chemical Engineering (AICHE) Annual Meeting*. Boston, MA.
4. **Pulsipher, J. L.**, Zhang, W., and Zavala, V. M. (July 2021). "InfiniteOpt.jl: A JuMP Extension for Tackling Infinite-Dimensional Optimization Problems". *Julia-Con*. Online.
3. **Pulsipher, J. L.**, Zhang, W., and Zavala, V. M. (Nov. 2020). "Modeling Infinite-Dimensional Optimization Problems with InfiniteOpt.jl". *The American Institute of Chemical Engineering (AICHE) Annual Meeting*. Online.
2. **Pulsipher, J. L.** and Zavala, V. M. (Nov. 2019). "A Scalable Stochastic Programming Approach for Designing Flexible Systems". *The American Institute of Chemical Engineering (AICHE) Annual Meeting*. Orlando, FL.

1. **Pulsipher**, **J. L.** and Zavala, V. M. (Nov. 2018). "A Mixed-Integer Conic Programming Formulation for Computing the Flexibility Index Under Multivariate Gaussian Random Variables". *The American Institute of Chemical Engineering (AICHE) Annual Meeting*. Pittsburg, PA.

Short Courses

3. **Pulsipher**, **J. L.** (June 2022). "InfiniteOpt.jl: A Julia Package for Infinite-Dimensional Optimization". *IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems (DYCOPS)*. Busan, South Korea.
2. **Pulsipher**, **J. L.** (May 2022). "InfiniteOpt.jl: A Julia Package for Infinite-Dimensional Optimization". *Carnegie Mellon University*. Pittsburg, PA.
1. **Pulsipher**, **J. L.** (Jan. 2022). "Julia: A Crash Course". *University of Wisconsin-Madison*. Madison, WI.

Posters

8. **Pulsipher**, **J. L.** (Nov. 2022). "Decision-Making and Learning Under Uncertainty for Complex Systems". *The American Institute of Chemical Engineering (AICHE) Annual Meeting*. Phoenix, AZ.
7. Kompalli, S., Merakli, M., Ammari, B. L., **Pulsipher**, **J. L.**, Qian, Y., Bynum, M. L., Furman, K. C., and Laird, C. D. (Sept. 2022). "Computational Performance of Algebraic Modeling Languages with Alternate Solver Interfaces and Advanced Modeling Components". *Enterprise-Wide Optimization (EWO) Annual Meeting*. Pittsburgh, PA.
6. **Pulsipher**, **J. L.**, Grossmann, I. E., Laird, C. D., and Zavala, V. M. (June 2022). "InfiniteOpt.jl: A Framework for Tackling Infinite-Dimensional Optimization Problems". *Advanced Manufacturing & Processing Conference (AMPc)*. Bethesda, MD.
5. **Pulsipher**, **J. L.**, Grossmann, I. E., Laird, C. D., and Zavala, V. M. (Mar. 2022). "InfiniteOpt.jl: A Framework for Tackling Infinite-Dimensional Optimization Problems". *Center for Advanced Process Decision-making (CAPD) Annual Meeting*. Pittsburg, PA.
4. **Pulsipher**, **J. L.** (Sept. 2021). "InfiniteOpt.jl: A Unifying Abstraction for Infinite-Dimensional Optimization". *LatinXChem*. Twitter.
3. **Pulsipher**, **J. L.** and Zavala, V. M. (Sept. 2018). "Analyzing and Quantifying the Flexibility of Complex Systems". *Machine Learning and Optimization Research (MOR) Meeting*. Madison, WI.
2. **Pulsipher**, **J. L.** and Zavala, V. M. (Sept. 2018). "Measures of System Resilience and Flexibility". *Texas-Wisconsin-California Control Consortium (TWCCC) Semi-Annual Meeting*. Madison, WI.
1. Martin, R. A., **Pulsipher**, **J. L.**, Lund, C., Clark, J., Franke, K., and Hedengren, J. D. (Aug. 2013). "UAV-Based Infrastructure Monitoring". *Center for Unmanned Aircraft Systems (C-UAS) Annual Meeting*. Snowbird, UT.

Research Mentoring

PhD Students

2022 – Present
- **Bashar Ammari,** Carnegie Mellon University
- **Daniel Ovalle,** Carnegie Mellon University

Master's Students

2023 – Present
- **Louis Tobergte,** Carnegie Mellon University

2022 – Present
- **Sai Kompalli,** Carnegie Mellon University

2022 – 2023
- **Shumeng Lin,** Carnegie Mellon University

2022 – 2022
- **Yicheng Xi,** Carnegie Mellon University
- **Yufeng Qian,** Carnegie Mellon University

Undergraduate Students

2021 – 2022
- **Baide Xue,** University of Wisconsin-Madison

2019 – 2022
- **Benjamin R. Davidson,** University of Wisconsin-Madison, Now at ExxonMobil

2020 – 2021
- **Luke D. J. Coutinho,** University of Wisconsin-Madison, Now at Koch Industries
- **Tyler J. Hongisto,** University of Wisconsin-Madison, Now at Proctor & Gamble

2018 – 2018
- **Daniel Rios,** University of Wisconsin-Madison, Now at Texas Instruments

Research Collaborators (Past 3 Years)

Universities

UW-Madison
- Victor Zavala (Chemical & Biological Eng.), Dan Negrut (Mechanical Eng.), Jim Luedtke (Industrial & Systems Eng.), Megan MacLean (Biomedical Eng.)

CMU
- Carl Laird, Ignacio Grossmann, David Bernal, Ana Torres, Coty Jen (Chemical Eng.)

Tufts
- Christos Georgakis (Chemical Eng.)

UNS (Argentina)
- Soledad Diaz (Chemical Eng.)

UFRJ (Brazil)
- Argimiro Secchi (Chemical Eng.)

National Laboratories

Argonne
- Mihai Anitescu, Sungho Shin (Mathematics & Computer Science)

Sandia
- Michael Bynum, Bill Hart, Emma Johnson (Discrete Math & Optimization)

NETL
- Miguel Zamarripa, Markus Drouven, Philip Tominac (Process Systems Eng.)

PNNL
- Zhenyu Huang (Optimization & Control), David Barajas-Solano, Jing Li (Computational Science & Mathematics)

Industry

ExxonMobil
- Tyler Soderstrom (Online Optimization & Control), Merve Merakli, Kevin Furman (Data & Decision Sciences)

ParallelWorks
- Michael Wilde, Alvaro Vidal, Matthew Shaxted

Service

Scientific

- **Session Organizer,** INFORMS 2021 (Julia Packages for the Modeling and Solution of Optimization Problems)
- **Workshop Organizer,** Pan-American Advanced Studies Institute (2022–present)
- **Organizing Committee Member,** UW-Madison CBE Computing Seminar Series (2020 – 2021)
- **Treasurer,** UW-Madison Chemical Engineering Graduate Student Association (2020 – 2021)
- **Session Chair,** INFORMS 2022, DYCOPS 2022, CORS/INFORMS 2022, INFORMS 2021
- **Journal Reviewer,** Computers & Chemical Engineering, AICHE Journal, Chemical Engineering Science, IEEE Transactions on Control Systems Technology

Community

- **Volunteer Leader,** LDS Church - Spanish Speaking (2019 – Present)
- **Volunteer,** LDS Church (2016 – Present)
- **Volunteer Missionary,** Peru Trujillo Mission - Spanish Speaking (2014 – 2016)
- **Volunteer,** Elderly Chore Services in Yakima, WA (2010 – 2012)
- **Volunteer Instructor,** Swim Lessons for All Project (2012)

Skills

Languages	Fluent in English and Spanish
Coding	Julia, Python, C, C++, Java, MATLAB, VBA, Bash, Android, Git, LaTeX, …
Web Dev	HTML, CSS, JavaScript, Markdown, Liquid
Modeling	JuMP, AMPL, Pyomo, Gekko, Simulink, Aspen, PyTorch, Keras, Flux