

# Zachary Nolan Sunberg

Ann and H. J. Smead Aerospace Engineering Sciences  
University of Colorado Boulder

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## Academic Appointments

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### Assistant Professor

[January 2020 – Present]

*University of Colorado, Boulder, CO*

Ann and H. J. Smead Aerospace Engineering Sciences

### Postdoctoral Research Scholar

[October 2018 – October 2019]

*University of California, Berkeley, CA*

Supervisor: Claire Tomlin, Hybrid Systems Laboratory

## Education

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### Doctor of Philosophy in Aeronautics and Astronautics

[2018]

*Stanford University, Stanford, CA*

Advisor: Mykel Kochenderfer | Thesis: "Safety and Efficiency in Autonomous Vehicles through Planning with Uncertainty"

### Master of Science in Aerospace Engineering

[2013]

*Texas A&M University, College Station, TX*

Advisor: Jonathan Rogers | Thesis: "A Real Time Expert Control System for Helicopter Autorotation"

### Bachelor of Science in Aerospace Engineering

[2011]

*Texas A&M University, College Station, TX*

Summa cum Laude, Minor in Mathematics

## Research

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### Hybrid Systems Laboratory

[October 2018 – October 2019]

*University of California, Berkeley, CA*

**Strategy alignment in differential games:** Developed particle filtering techniques to deal with the presence of multiple Nash equilibria in differential games and coordinate strategies with humans that robots interact with [10].

**Analysis of online algorithms for continuous POMDPs:** Developed the first proof of convergence to optimality for an online sampling-based POMDP algorithm in continuous observation spaces [9].

**Reachability-based safety constraints in partially observable domains:** Combining Hamilton-Jacobi reachability analysis with partial observability, focused on problems with human interaction; using POMDP planners to find optimized feedback policies that are aware of the reachability-based safety constraints.

### Stanford Intelligent Systems Laboratory (SISL)

[2015 – 2018]

*Stanford University, Stanford, CA*

**POMCPOW:** Proved analytically that leading online POMDP solvers converge to suboptimal solutions for problems with continuous observation spaces and proposed a new algorithm, partially observable Monte Carlo planning with observation widening (POMCPOW) as a solution [12].

**Behavior-aware decision making in self-driving cars:** Showed that modeling the internal states of other human drivers and approximately solving the resulting POMDP can simultaneously improve both safety and efficiency. In particular, a multiple-lane-change maneuver on a highway can be accomplished in about half the time while still maintaining the same levels of safety and comfort [13]. Other students are currently collaborating with me to .

**Adaptive control with belief space MCTS:** Solved adaptive control problems (i.e. problems where some dynamics parameters are unknown) by modeling them as POMDPs and using Monte Carlo tree search (MCTS) in the belief space. This approach achieved superior results in cases with large uncertainty [14, 1].

**Autonomous Systems Laboratory (ASL)** [2014 – 2016]  
*Stanford University, Stanford, CA*

**UAV collision avoidance:** Developed a method to dynamically optimize the performance a trusted collision avoidance system without sacrificing certifiability [15].

**Hansen Experimental Physics Lab** [2013 – 2014]  
*Stanford University, Stanford, CA*

**Geostationary LISA:** Investigated gravitational coupling between a drag free test mass and a communications satellite carrying it for a laser interferometer gravity wave experiment.

**Helicopters and Unmanned Systems Laboratory (HUSL)** [2011 – 2013]  
*Texas A&M University, College Station, TX*

**Autonomus autorotation:** Created a control system for autonomous autorotation of manned and unmanned helicopters, and successfully flight tested it on a small RC helicopter [4]. Currently advising a team at the Air Force Research Lab on an autorotation-based delivery system.

**Distance metrics for Dempster Shafer theory:** Developed a distance metric for Dempster-Shafer theory that applies to orderable and continuous sets like those encountered in the real world [6].

**Air Force Research Lab Summer Faculty Program (Research Assistant)** [Summer 2011]  
*Kirtland AFB, Albuquerque, NM*

**Space situational awareness:** Developed an online algorithm for managing uncertainty about orbital vehicles and debris with a network of sensors [3].

## Teaching

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**Army High Performance Computing Summer Institute** [June 2017]  
*Stanford University, Stanford, CA*

Developed and taught a 5 lecture course about decision making under uncertainty for college students.

**Stanford Artificial Intelligence Lab OutReach Summer (SAILORS, now AI4ALL)** [2015-2017]  
*Stanford University, Stanford, CA*

Developed and taught a 2 week course and project for high school students that included programming robots for optical line following and using Dijkstra's algorithm to find the shortest path on a road network; only project mentor to serve all three years of the program. <http://ai-4-all.org/>

**AA-228/CS-238 Decision Making Under Uncertainty** [Autumn 2016]  
*Stanford University, Stanford, CA*

Head course assistant for a class of around 200; developed problems for midterm project; gave guest lectures on the POMDPs.jl framework and autonomous driving research; project software was reused in a course at Iowa State University.

## Talks

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**Invited Industry Talks** [2018]

**Renault-Nissan Research, Sunnyvale, CA:** Safety and Efficiency in Autonomous Vehicles through POMDP Planning

**Lyft Level 5, Palo Alto, CA:** Safety and Efficiency in Autonomous Vehicles through Planning with Uncertainty

**Makani (Google X), Alameda, CA:** Algorithms for Uncertain, Non-convex Control Problems in the Real World

**Indeed, San Francisco, CA:** Safety and Efficiency in Autonomous Vehicles through Planning with Uncertainty

**Julia in Controls Workshop** [May 2017]  
*American Control Conference, Seattle, WA*

Taught a tutorial of the POMDPs.jl software package at a workshop at the American Control Conference.

**POMDPs.jl - Challenges and Lessons Learned** [March 2017]  
*Open Source Software for Decision Making (OSS4DM), Stanford, CA*

Presented and discussed the challenges that we faced and lessons that we learned in creating POMDPs.jl.

## Industry Experience

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**Google, Inc.**, Mountain View, CA [Summer 2014]  
*Software Engineering Intern*

Wrote software to evaluate and optimize a NASA collision avoidance program for use with Google self-piloted air vehicles.

**Lockheed Martin Autonomous Systems**, Littleton, CO [Summer 2009]  
*Intern*

Helped in testing of autonomous SMSS allterrain military transport vehicle navigation system; wrote rough terrain navigation program in C++ based on the A\* search algorithm; wrote software in C++ for analyzing the performance of an advanced video analysis tool.

## Fellowships and Awards

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**National Science Foundation Graduate Research Fellowship** [2012-2016]  
**Association for the Advancement of Artificial Intelligence Doctoral Consortium** [February 2018]  
**IJCAI 2019 Distinguished Program Committee member** [2019]  
**American Control Conference Student Travel Award** [May 2017]

## Open Source Software

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**POMDPs.jl** [2015 – present]

<https://github.com/JuliaPOMDP/POMDPs.jl>

Interface for defining continuous and discrete, fully and partially observable Markov decision processes along with a suite of state-of-the-art solvers written in Julia and C++.

## Review Experience

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I have reviewed submissions for the following journals and conferences:

Journal of Artificial Intelligence Research	International Symposium on Robotics Research
IEEE Robotics and Automation Letters	Intl. Conference on Robotics and Automation (ICRA)
IEEE Transactions on Cybernetics	Intl. Joint Conference on Artificial Intelligence (IJCAI)
IEEE Transactions on Intelligent Transportation Systems	AAAI Conference on Artificial Intelligence
IEEE Transactions on Intelligent Vehicles	American Control Conference (ACC)
Journal of Aerospace Information Systems	Intelligent Transportation Systems Conference (ITSC)
Autonomous Robots	Robotics, Science and Systems (RSS)
Journal of the American Helicopter Society	

## Peer Reviewed Journal Publications

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- [1] Patrick Slade, **Zachary Sunberg**, and Mykel J. Kochenderfer. “Estimation and Control Using Sampling-Based Bayesian Reinforcement Learning”. In: *IET Cyber-Physical Systems: Theory and Applications* 5 (1 2020). URL: [↗](#).
- [2] Maxim Egorov, **Zachary N. Sunberg**, Edward Balaban, Tim A. Wheeler, Jayesh K. Gupta, and Mykel J. Kochenderfer. “POMDPs.jl: A Framework for Sequential Decision Making under Uncertainty”. In: *Journal of Machine Learning Research* 18.26 (2017). URL: [↗](#).
- [3] **Zachary Sunberg**, Suman Chakravorty, and Richard Scott Erwin. “Information Space Receding Horizon Control for Multisensor Tasking Problems”. In: *IEEE Transactions on Cybernetics* 46.6 (2016). URL: [↗](#).
- [4] **Zachary N. Sunberg**, Nathaniel R. Miller, and Jonathan D. Rogers. “A Real-Time Expert Control System For Helicopter Autorotation”. In: *Journal of the American Helicopter Society* 60.2 (2015). DOI: 10.4050/JAHS.60.022008. URL: [↗](#).
- [5] **Zachary Sunberg**, Suman Chakravorty, and Richard Scott Erwin. “Information Space Receding Horizon Control”. In: *IEEE Transactions on Cybernetics* 43.6 (2013). URL: [↗](#).

- [6] **Zachary Sunberg** and Jonathan Rogers. "A Belief Function Distance Metric for Orderable Sets". In: *Information Fusion* 14.4 (2013). DOI: 10.1016/J.INFFUS.2013.03.003. URL: [↗](#).

## Peer Reviewed Conference Publications

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- [7] Shakeeb G. Ahmad, **Zachary Sunberg**, and Sean Humbert. "APF-PF: Probabilistic Depth Perception for 3D Reactive Obstacle Avoidance". In: *American Control Conference (ACC)*. 2021.
- [8] John Mern, Anil Yildiz, **Zachary Sunberg**, Tapan Mukerji, and Mykel J. Kochenderfer. "Bayesian Optimized Monte Carlo Planning". In: *AAAI Conference on Artificial Intelligence (AAAI)*. 2021.
- [9] Michael H. Lim, Claire J. Tomlin, and **Zachary N. Sunberg**. "Sparse Tree Search Optimality Guarantees in POMDPs with Continuous Observation Spaces". In: *International Joint Conference on Artificial Intelligence (IJCAI)*. 2020.
- [10] Lasse Peters, David Fridovich-Keil, Claire Tomlin, and **Zachary Sunberg**. "Inference-Based Strategy Alignment for General-Sum Differential Games". In: *International Conference on Autonomous Agents and Multiagent Systems (AAMAS)*. 2020. URL: [↗](#).
- [11] Ekhlās Sonu, **Zachary Sunberg**, and Mykel J. Kochenderfer. "Exploiting Hierarchy for Scalable Decision Making in Autonomous Driving". In: *Intelligent Vehicles Symposium*. 2018.
- [12] **Zachary N. Sunberg** and Mykel J. Kochenderfer. "Online Algorithms for POMDPs with Continuous State, Action, and Observation Spaces". In: *International Conference on Automated Planning and Scheduling (ICAPS)*. 2018. URL: [↗](#).
- [13] **Zachary N. Sunberg**, Christopher J. Ho, and Mykel J. Kochenderfer. "The Value of Inferring the Internal State of Traffic Participants for Autonomous Freeway Driving". In: *American Control Conference (ACC)*. 2017. URL: [↗](#).
- [14] Patrick Slade, Preston Culbertson, **Zachary Sunberg**, and Mykel J. Kochenderfer. "Simultaneous Active Parameter Estimation and Control using Sampling-based Bayesian Reinforcement Learning". In: *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2017. URL: [↗](#).
- [15] **Zachary Sunberg**, Mykel J. Kochenderfer, and Marco Pavone. "Optimized and Trusted Collision Avoidance for Unmanned Aerial Vehicles using Approximate Dynamic Programming". In: *IEEE International Conference on Robotics and Automation (ICRA)*. 2016. URL: [↗](#).
- [16] **Zachary Sunberg**, Suman Chakravorty, and Richard Erwin. "Information space sensor tasking for Space Situational Awareness". In: *American Control Conference (ACC)*. June 2014. DOI: 10.1109/ACC.2014.6858922.
- [17] **Zachary Sunberg**, Nathaniel Miller, and Jonathan Rogers. "A Real Time Expert Control System for Helicopter Autorotation". In: *70th Forum of the American Helicopter Society*. 2014.
- [18] **Zachary Sunberg** and Jonathan Rogers. "A Fuzzy Logic-Based Controller for Helicopter Autorotation". In: *AIAA Aerospace Sciences Meeting*. 2013.
- [19] **Zachary Sunberg**, Suman Chakravorty, and Richard Erwin. "Information Space Receding Horizon Control for MultiAgent Systems". In: *American Control Conference (ACC)*. 2012. URL: [↗](#).

## Forthcoming Publications

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- [20] Michael H. Lim, Claire J. Tomlin, and **Zachary N. Sunberg**. "Voronoi Progressive Widening: Efficient Online Solvers for Continuous Space MDPs and POMDPs with Provably Optimal Components". Under Review for ICAPS. 2021.
- [21] **Zachary Sunberg** and Mykel Kochenderfer. "Improving Automated Driving through Planning with Human Internal States". Submitted to *IEEE Transactions on Intelligent Transportation Systems*. URL: [↗](#).