Abolfazl Lavaei, Dr.-Ing.

Postdoctoral Research Fellow

Chair of Software and Computational Systems
Department of Computer Science
Ludwig Maximilian University of Munich (LMU)

Office: Room F U109
Oettingenstr. 67
80538 Munich, Germany

Tel: +49 89 2180-9345
Fax: +49 89 2180-9175

Email: lavaei@lmu.de
lavaei@tum.de
Web: www.lavaei.de

Brief Biography

My line of research focuses mainly on theoretical and practical aspects of "automated (AI-based) verification and control of large-scale stochastic cyber-physical systems" with application to *autonomous vehicles*. My research interests revolve around the intersection of Control Theory, Optimization, Machine Learning, Artificial Intelligence, and Data Science, for which I employ compositional formal methods, reinforcement learning/deep learning, data-driven optimization, and advanced (parallel) programming in C++/Python/OpenCL.

Academic Positions/Degrees

Nov'19 - Present **Postdoctoral Research Fellow (Group Leader)** in Computer Science, Software and Computational Systems, Ludwig Maximilian University of Munich (LMU), Germany

ERC Project: *Automated Synthesis of Cyber-Physical Systems: A Compositional Approach*

Nov'16 - Oct'19 **Ph.D.** in Electrical Engineering, Hybrid Systems & Control, Technical University of Munich (TUM), Germany

Dissertation: *Automated Verification and Control of Large-Scale Stochastic Cyber-Physical Systems: Compositional Techniques*

Nov'16 - Oct'19 **Scientific Researcher** in Munich Aerospace & German Aerospace Center (DLR), Autonomous Flight Research Group, Germany

Topic: *Certifiable Autonomy in Unmanned Aerial Vehicles (UAVs)*

May'19 - Aug'19 **Visiting Researcher** in Delft Center for Systems and Control, Delft University of Technology (TUD), The Netherlands

Topic: *Formal Verification and Synthesis of Unknown Stochastic Hybrid Systems via "Data-driven Optimization"*

Sep'13 - Sep'14 **M.Sc.** in Aerospace Engineering, Flight Dynamics & Control, University of Tehran, Iran

Thesis: *3D Constrained Optimal Motion Planning and Robust Tracking Control for a 6DoF Quadcopter*

Research Interests

- Formal Learning & Control
- Safe Automated Vehicles
- Artificial Intelligence
- Data-Driven Optimization
- Decision-making in Uncertain & Dynamic Environments
- Large-Scale Stochastic Networks
- Compositional Formal Methods w.a.t. Robotics
- Cyber-Physical Systems
- Advanced (Parallel) Programming

Honors & Awards

2020 **Best Demo/Poster Award** at the *23rd ACM International Conference on Hybrid Systems: Computation and Control (HSCC)*, Sydney, Australia. **News: Munich Aerospace**

2019 Received the Ph.D. degree in **three years**, Department of Electrical and Computer Engineering, *Technical University of Munich (TUM)*, Germany.

2019 Distinguished as **"highly-qualified scientists"** for *permanent residence of Germany* (**Niederlassungserlaubnis für Hochqualifizierte**).

2019 **IFAC Young Author Award Finalist**, at the *15th IFAC Symposium on Large-Scale Complex Systems: Theory and Applications (LSS)*, Delft, The Netherlands. **News: Munich Aerospace**

2016 Recipient of **Munich Aerospace Doctoral Scholarship**, Department of Electrical and Computer Engineering, *Technical University of Munich (TUM)*, Germany.

2016 Recipient of **University of Auckland Doctoral Scholarship**, Department of Electrical and Computer Engineering, *University of Auckland*, New Zealand.

2016 Recipient of **Concordia International Award of Excellence**, Department of Electrical and Computer Engineering, *Concordia University*, Canada.

2016 Admitted by **EDEE Doctoral Program Committee**, Department of Electrical Engineering, *École Polytechnique Fédérale De Lausanne (EPFL)*, Switzerland.

2016 Admitted by **Doctoral Program Committee**, Department of Mechanical Engineering, *University of Melbourne*, Australia.

2015 Recipient of **Departmental Prestigious Doctoral Fellowship**, Department of Mechanical and Aerospace Engineering, *University of California at San Diego (UCSD)*, United States.

2015 **Best Graduate Student Award** in *all fields of study* at Faculty of New Sciences and Technologies, *University of Tehran*, Iran.

2014 **First & Only Graduate Student Nationwide** who managed to receive a two-year Master of Science degree in *two semesters* **(one academic-year)** with the *full GPA* **(20 out of 20)**, German scale: 1.

Advanced Software Development in "C++/OpenCL"

AMYTISS: PArallelized AutoMated Controller SYnthesis of Large-Scale STochastIc SystemS; An advanced software tool developed in C++/OpenCL that provides parallel automated controller synthesis for large-scale discrete-time stochastic control systems which is absolutely crucial in many safety-critical applications such as *autonomous driving*. This tool allows to:

(i) build finite Markov decision processes (MDPs) as finite abstractions of given original systems;

(ii) synthesize automated controllers for the constructed finite MDPs satisfying some high-level specifications (*e.g.,* safety, reachability & reach-avoid).

AMYTISS enjoys high-performance computing (HPC) platforms together with cloud-computing services to mitigate the problem of state-explosion which is always the case in analyzing large-scale stochastic systems. This tool significantly improves performances w.r.t. *memory usage* and *computation time* by parallel execution in different heterogeneous computing platforms including CPUs, GPUs and hardware accelerators (HWAs).

Publications

Preprints

[P2] B. Zhong, **A. Lavaei**, H. Cao, M. Zamani, and M. Caccamo, "Towards Safe AI: Safe-visor Architecture for Sandboxing AI-based Controllers in Stochastic Cyber-Physical Systems", *submitted for publication*, 2020.

[P1] **A. Lavaei**, and M. Zamani, "From Dissipativity Theory to Compositional Synthesis of Large-Scale Stochastic Switched Systems", *submitted for publication*, 2020.

Journal Papers

[J12] **A. Lavaei**, S. Soudjani, and M. Zamani, "Compositional Abstraction-based Synthesis of General MDPs via Approximate Probabilistic Relations", *Nonlinear Analysis: Hybrid Systems*, to appear, 2020.

[J11] **A. Lavaei**, S. Soudjani, A. Abate, and M. Zamani, "Automated Verification and Synthesis of Stochastic Hybrid Systems: An Overview". *Automatica*, accepted as a survey paper proposal, 2020.

[J10] **A. Lavaei**, S. Soudjani, and M. Zamani, "Compositional Abstraction-based Synthesis for Networks of Stochastic Switched Systems". *Automatica*, vol. 114, 2020.

[J9] **A. Lavaei**, S. Soudjani, and M. Zamani, "Compositional (In)Finite Abstractions for Large-Scale Interconnected Stochastic Systems". *IEEE Transactions on Automatic Control*, DOI: 10.1109/TAC.2020.2975812, 2020.

[J8] **A. Lavaei**, S. Soudjani, and M. Zamani, "Compositional Abstraction of Large-Scale Stochastic Systems: A Relaxed Dissipativity Approach". *Nonlinear Analysis: Hybrid Systems*, vol. 36, 2020.

[J7] **A. Lavaei**, S. Soudjani, and M. Zamani, "Compositional Construction of Infinite Abstractions for Networks of Stochastic Control Systems", *Automatica*, vol. 107, pp. 125-137, 2019.

[J6] **A. Lavaei**, and M.A. Atashgah, "Optimal 3D Trajectory Generation in Delivering Missions under Urban Constraints for a Flying Robot", *Intelligent Service Robotics*, vol. 10, no. 3, pp. 241-256, 2017.

[J5] A. Kosari, H. Maghsoudi, and **A. Lavaei**, "Path Generation for Flying Robots in Mountainous Regions", *International Journal of Micro Air Vehicles*, vol. 9, no. 1, pp. 44-60, 2017.

[J4] M.A. Atashgah, H. Gazerpour, **A. Lavaei**, and Y. Zarei, "An Active Time-optimal Control for Space Debris Deorbiting via Geomagnetic Field", *Celestial Mechanics and Dynamical Astronomy*, vol. 128, no. 2-3, pp. 343-360, 2017.

[J3] M.A. Atashgah, M.R. Torkamani, and **A. Lavaei**, "Robust Positioning, Preliminary Orbit Determination, and Trajectory Prediction of Space Debris using In-Space Iterative-Bearing-Only Observations", *The Journal of Navigation*, vol. 70, no. 4, pp. 789-809, 2017.

[J2] **A. Lavaei**, and M.A. Atashgah, "Three-Dimensional Constrained Optimal Motion Planning for a Six-Degree-of-Freedom Quadrotor for Urban Traffic Purposes", *Modares Mechanical Engineering*, vol. 15, no. 5, pp. 13-24, 2015.

[J1] A. Kosari, H. Maghsoudi, **A. Lavaei**, and R. Ahmadi, "Optimal Online Trajectory Generation for a Flying Robot for Terrain Following Purposes using Neural Network", *Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering*, vol. 229, no. 6, pp. 1124-1141, 2014.

Book Chapters

[B2] **A. Lavaei***, M. Khaled*, S. Soudjani, and M. Zamani, "AMYTISS: Parallelized Automated Controller Synthesis of Large-Scale Stochastic Systems", *32nd International Conference on Computer-Aided Verification (CAV)*, Lecture Notes in Computer Science 12225, pp. 461-474, Springer, 2020.

[B1] **A. Lavaei**, S. Soudjani, and M. Zamani, "Approximate Probabilistic Relations for Compositional Synthesis of Stochastic Systems", *Numerical Software Verification*, Lecture Notes in Computer Science 11652, pp. 101–109, Springer, 2019.

Conference Papers

[C12] A. Abate, H. Blom, N. Cauchi, J. Delicaris, A. Hartmanns, M. Khaled, **A. Lavaei**, C. Pilch, A. Remke, S. Schupp, F. Shmarov, S. Soudjani, A. P. Vinod, B. Wooding, M. Zamani, and P. Zuliani, "ARCH-COMP20 Category Report: Stochastic Models", *21st IFAC World Congress*, to appear, 2020.

[C11] M. Anand*, **A. Lavaei***, and M. Zamani, "Compositional Construction of Control Barrier Certificates for Large-Scale Interconnected Stochastic Systems", *21st IFAC World Congress*, to appear, 2020.

[C10] **A. Lavaei***, M. Khaled*, S. Soudjani, and M. Zamani, "AMYTISS: A Parallelized Tool on Automated Controller Synthesis for Large-Scale Stochastic Systems", *23rd ACM International Conference on Hybrid Systems: Computation and Control (HSCC)*, pp. 1-2, 2020. **(Best Demo/Poster Award)**

[C9] **A. Lavaei**, F. Somenzi, S. Soudjani, A. Trivedi, and M. Zamani, "Formal Controller Synthesis for Continuous-Space MDPs via Model-Free Reinforcement Learning", *11th ACM/IEEE Conference on Cyber-Physical Systems (ICCPS)*, pp. 98-107, 2020.

*Both authors have contributed equally.

[C8] **A. Lavaei**, and M. Zamani, "Compositional Verification of Large-Scale Stochastic Systems via Relaxed Small-Gain Conditions", *58th IEEE Conference on Decision and Control (CDC)*, pp. 2574-2579, 2019.

[C7] **A. Lavaei**, S. Soudjani, and M. Zamani, "Compositional Synthesis of not Necessarily Stabilizable Stochastic Systems via Finite Abstractions", *18th European Control Conference (ECC)*, pp. 2802–2807, 2019.

[C6] **A. Lavaei**, and M. Zamani, "Compositional Construction of Finite MDPs for Large-Scale Stochastic Switched Systems: A Dissipativity Approach", *15th IFAC Symposium on Large-Scale Complex Systems: Theory and Applications (LSS)*, vol. 52, no. 3, pp. 31-36, 2019. **(IFAC Young Author Award Finalist)**

[C5] **A. Lavaei**, and M. Zamani, "Compositional Finite Abstractions for Large-Scale Stochastic Switched Systems", *5th International Workshop on Symbolic-Numeric Methods for Reasoning about CPS and IoT (SNR) in conjunction with Cyber-Physical Systems and Internet-of-Things Week (CPS-IoT Week)*, pp. 3-5, 2019.

[C4] **A. Lavaei**, S. Soudjani, and M. Zamani, "Compositional Synthesis of Finite Abstractions for Continuous-Space Stochastic Control Systems: A Small-Gain Approach", *6th IFAC Conference on Analysis and Design of Hybrid Systems (ADHS)*, vol. 51, no. 16, pp. 265-270, 2018.

[C3] **A. Lavaei**, S. Soudjani, and M. Zamani, "Compositional Synthesis of Interconnected Stochastic Control Systems based on Finite MDPs", *21st ACM International Conference on Hybrid Systems: Computation and Control (HSCC)*, pp. 273-274, 2018.

[C2] **A. Lavaei**, S. Soudjani, and M. Zamani, "From Dissipativity Theory to Compositional Construction of Finite Markov Decision Processes", *21st ACM International Conference on Hybrid Systems: Computation and Control (HSCC)*, pp. 21-30, 2018.

[C1] **A. Lavaei**, S. Soudjani, R. Majumdar, and M. Zamani, "Compositional Abstractions of Interconnected Discrete-Time Stochastic Control Systems", *56th IEEE Conference on Decision and Control (CDC)*, pp. 3551-3556, 2017.

Dissertations

[Ph.D.] **A. Lavaei**, "Automated Verification and Control of Large-Scale Stochastic Cyber-Physical Systems: Compositional Techniques,", Ph.D. Dissertation, *Technical University of Munich (TUM)*, Germany, 2019.

[M.Sc.] **A. Lavaei**, "3D Constrained Optimal Motion Planning and Robust Tracking Control for a 6DoF Quadcopter", M.Sc. Thesis, *University of Tehran (UT)*, Iran, 2014.

Advanced Courses Taken in 2016 - 2019 (Ph.D.)

- Optimization Methods for Large-scale Networks
- Reinforcement Learning in Robotics
- Formal Synthesis of Embedded Systems
- Probability Theory
- Markov Processes
- Functional Analysis
- Programming in C++

Advanced Courses Taken in 2013 - 2014 (M.Sc.)

- Guidance & Navigation
- Advanced Flight Dynamics
- Advanced Automatic Control
- Nonlinear Control
- Optimal Control
- Robust Control
- Digital Control
- Advanced Engineering Mathematics

Conference Presentations

Apr'20 11th ACM/IEEE Conference on Cyber-Physical Systems (ICCPS), Sydney, Australia

Jun'19 18th European Control Conference (ECC), Naples, Italy

May'19 15th IFAC Symposium on Large-Scale Complex Systems: Theory and Applications (LSS), Delft, The Netherlands

Jul'18 Munich Aerospace Summer School, Glonn, Germany

Apr'18 21st ACM International Conference on Hybrid Systems: Computation and Control (HSCC), Porto, Portugal

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Seminar/Workshop Attendance

2019 Munich Aerospace Board of Trustees Meeting, **Munich Aerospace**, Taufkirchen/Ottobrunn, Germany

2019 Scientific Presentation, **DLR**, Oberpfaffenhofen, Germany

2019 Fit for Germany, **DLR**, Oberpfaffenhofen, Germany

2018 Deep Learning Workshop, **LRZ**, Munich, Germany

2018 **Munich Aerospace Summer School**, Glonn, Germany

2018 Partner Event: Long-Term Development of Aviation - Future Drivers and Key Technologies, **Bauhaus Luftfahrt (BHL)**, Taufkirchen/Ottobrunn, Germany

2018 Basic Project Management Skills, **DLR**, Oberpfaffenhofen, Germany

2018 Effective Reading, **DLR**, Oberpfaffenhofen, Germany

2017 Partner Event: Laboratory Tours at Department of Aerospace Engineering, **UniBw**, Neubiberg, Germany

2017 **Munich Aerospace Summer Summit** on Green Aerospace, Taufkirchen/Ottobrunn, Germany

2017 Workshop on Information and Communication Theory in Control Systems, **TUM**, Germany

2017 Kick-Off Seminar on Scientific Paper Writing, **TUM**, Germany

2017 Writing Readable Scientific Papers, **DLR**, Oberpfaffenhofen, Germany

2017 The Basics of Communication, **DLR**, Oberpfaffenhofen, Germany

2017 Professional Communication in Scientific Environments, **DLR**, Oberpfaffenhofen, Germany

2017 Mastering the Ph.D. Study, **DLR**, Oberpfaffenhofen, Germany

2016 Partner Event: Laboratory Tours, **DLR**, Oberpfaffenhofen, Germany

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Academic Services: Reviewing Activities

- Journals: IEEE Transaction on Automatic Control (TAC, IEEE), Automatica (Elsevier), Nonlinear Analysis: Hybrid Systems (NAHS, Elsevier)

- Conferences: IEEE Conference on Decision and Control (CDC), IEEE European Control Conference (ECC), IEEE American Control Conference (ACC), IEEE Indian Control Conference (ICC), IFAC Conference on Analysis and Design of Hybrid Systems (ADHS), IFAC World Congress

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Technical Skills

- Programming Language: C++, Python, MATLAB (GUI and Simulink)

- Operating System: Microsoft Windows, iOS, Linux

Languages

- English: Full professional proficiency

- German: B2.2

Professional Memberships

- Munich Aerospace Research Group (as an alumni)
- DLR Graduate Program (as an alumni)
- Institute of Electrical and Electronics Engineers (IEEE): Control Systems Society
- IEEE Technical Committee on Hybrid Systems

References

- Prof. Dr. Majid Zamani: Department of Computer Science, University of Colorado Boulder, USA. Department of Computer Science, Ludwig Maximilian University of Munich, Germany. Email: Majid.Zamani@colorado.edu

- Prof. Dr. Sadegh Soudjani: School of Computing, Newcastle University, United Kingdom, Email: Sadegh.Soudjani@newcastle.ac.uk

- Prof. Dr. Peyman Mohajerin Esfahani: Delft Center for Systems and Control , Delft University of Technology, The Netherlands, Email: P.MohajerinEsfahani@tudelft.nl

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